A COLLECTION AND STATISTICAL ANALYSIS
OF BIOPHYSICAL DATA TO PREDICT
MOTION SICKNESS INCIDENCE

THESIS

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirement for the Degree of
Master of Science of Computer Systems

Michael R. McPherson
Captain, USAF

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Preface

The goal of this thesis project was to continue to collect biophysical data on volunteers as they experienced symptoms of motion sickness and then statistically analyze the data in order to identify predictive parameters of motion sickness. Although this thesis report is an individual product, I would like to express my gratitude by acknowledging those people who assisted me and gave their support.

I would like to especially thank Dr. Matthew Kabrisky, my thesis advisor, for his experience and guidance. I am also grateful to Dr. William Czelen for sharing his expertise in human physiology and biomedical engineering. I would like to thank Mr. Robert Durham and Mr. Daniel Zambon who provided constant hardware and system support throughout this project. I thank my thesis committee, Dr. Lynn Wolaver and Dr. Charles Hatsell. A special thanks goes to my collegues Captain Robert Miller and Captain Dana Hartle whose ideas, encouragement, and friendship are appreciated more than they will ever know.

Finally, I would like to extend my sincerest thanks and love to my wife Darlene and my daughters Kelly and Krysten for their love and understanding that helped me to reach my goal at AFIT.

Mike McPherson

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Abstract

Biophysical data were collected on human volunteers to study the effects of the motion sickness syndrome. Physiological parameters were analyzed by descriptive statistical methods and by means of a spectrum analyzer. Descriptive statistical anaysis showed at least five separate physiological parameters were linearly correlated to a motion sickness symptom index. Spectral analysis showed definite frequency and amplitude shifts during the onset of motion sickness for various parameters. Low frequency brain wave activity on the order of 0.1 Hz was discovered as the subject approached nausea.

A multiple linear regression model was constructed from the correlated data obtained by descriptive statistics. Six separate physiological parameters were useful in describing a predictive motion sickness model that can be used as a major construct in developing a complete biofeedback system for countering effects of motion sickness.

A Collection and Statistical Analysis of Biophysical Data to Predict Motion Sickness Incidence

I Introduction

Background

Motion sickness is a malady that affects the entire human species, from the child that gets sick traveling in an automobile to the most experienced fighter pilot who experiences unusual acceleratory forces. Motion sickness also may affect the astronaut who must function under the abnormal weightless conditions in the space environment (24:31). The study of motion sickness is important to any organization that operates in a motion environment, particularly the Air Force. Efforts to counteract motion sickness have included drug therapy, desensitization, and biofeedback training. Most of the research effort has been conducted by the National Aeronautics and Space Administration (NASA) and the Air Force in order to identify the causes and mechanisms of motion sickness and establishing an effective treatment.

The first major contribution of understanding the cause of motion sickness came in 1881 when Irwin described the cause as follows:

> Foremost among the physiological facts revealed by the brilliant experiments of the past half century is the knowledge that our bodies are endowed with what may be termed a supplementary sense, quite independent of, but at the same time in the closest alliance with, our other special senses, the function of which is "to determine the position of the head in space", and to govern and direct the aesthetiko-kinetic mechanism by

> which is maintained the equilibrium of the body. This faculty of equilibrium appears to be more or less connected with the cerebellum, the optic lobes, and possibly other parts of the nervous organisation, but beyond doubt its principal seat is in the semicircular canals of the internal ear, which may for practical purposes be regarded as the organs of equilibration (25:7).

Thus, the semicircular canals in the inner ear (see Figure 1) were recognized more than one hundred years ago as the means by which we detect angular accelerations and rotational movement.

Motion sickness can be evoked in an individual by stimulating the semicircular canals in the inner ear with cross coupled angular accelerations that occur when the head position is moved out of the axis of rotation (13:229). This effect was principally studied by McIntyre and later came to be called "Coriolis accelerations" (25:20). The Coriolis illusion is elicited by tilting the head about axes other than the axis of bodily rotation. Such head motions deliver a Coriolis accelerative stimulus (cross-coupled angular acceleration) to the canal system, and produce illusory sensations of perceived motion and whole body rotation about an axis that is orthogonal to both the head-tilt and rotational axis (25 :49). The magnitude and persistance of these sensations is a function of the speed of rotation, the angle through which the head is tilted, and the direction of the head movement (25:49). Motion sickness is an almost inevitable consequence of continued exposure to Coriolis accelerations if the angular speed of the rotating device is sufficient to exceed the subject's personal tolerance threshold. Specifically, if an individual seated on a rotating litter chair

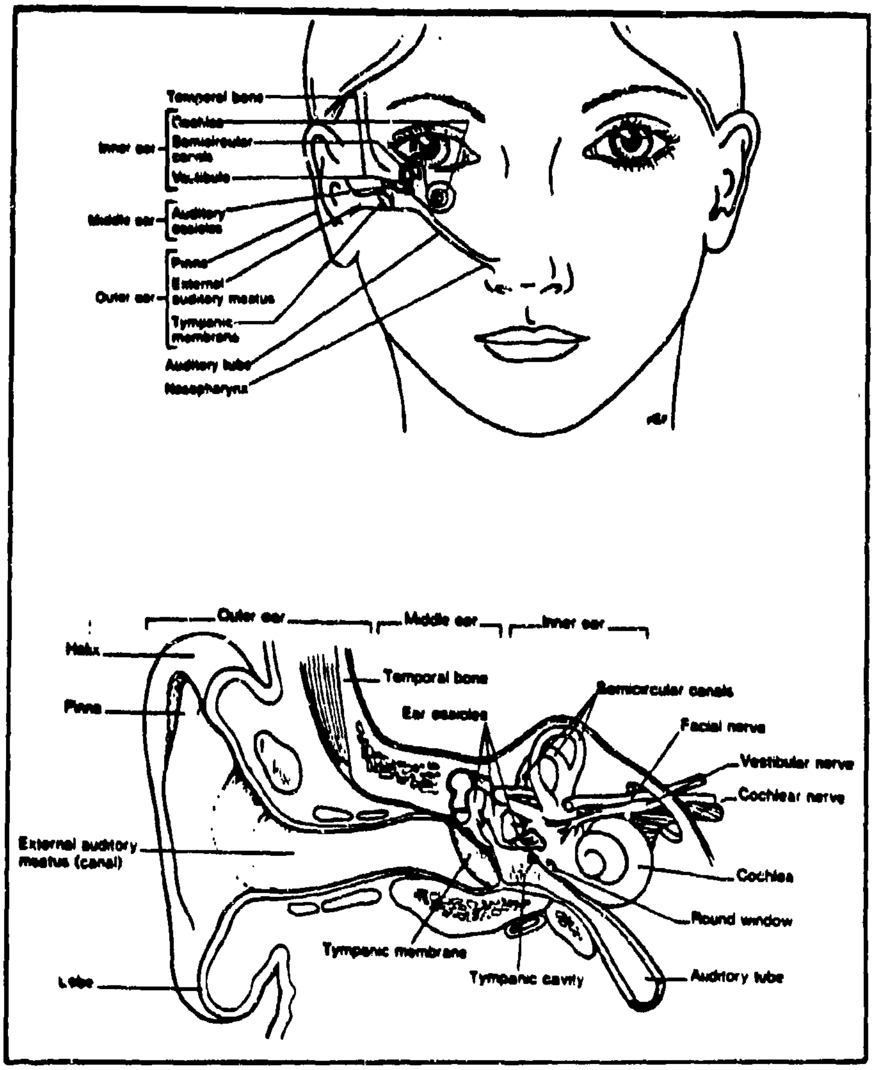


Figure 1 The Vestibular Cavity

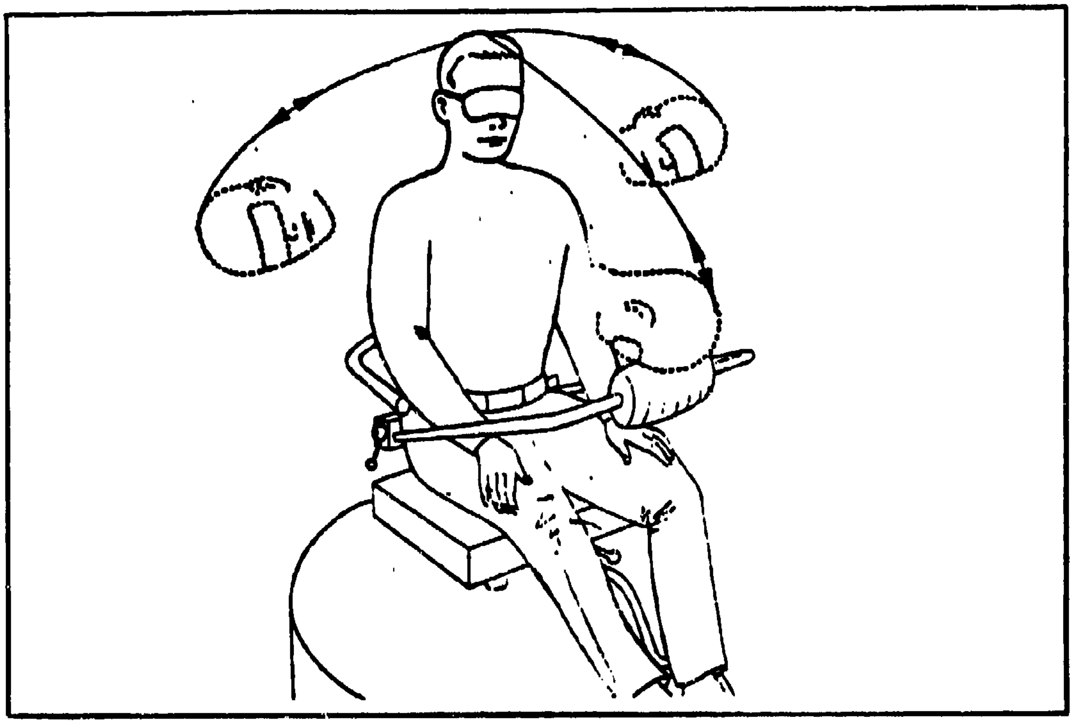


Figure 2 Schematic illustration of rotating chair used to induce motion sickness response (22:602).

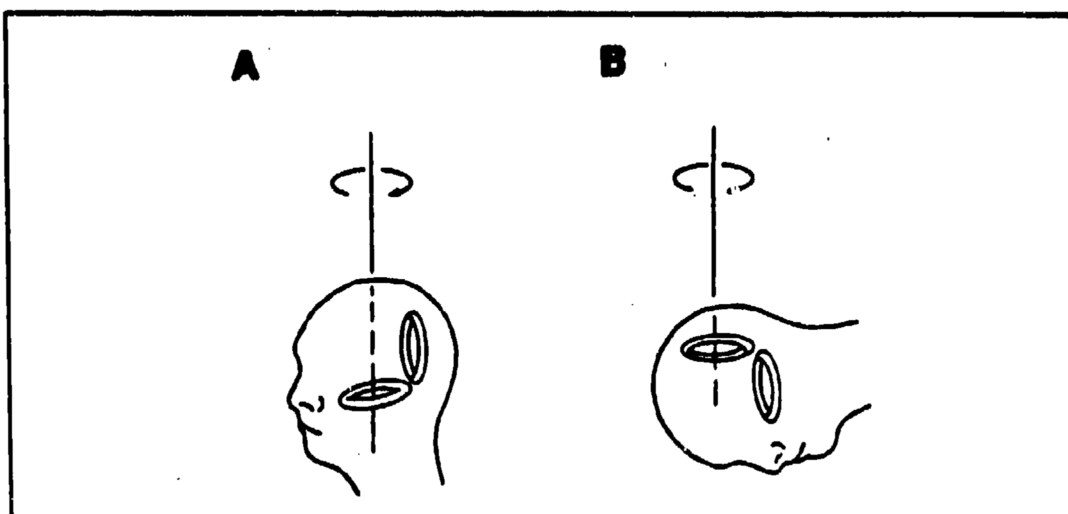


Figure 3 Schematic illustration of cross-coupling. If an individual rotates clockwise at a constant velocity and tilts his head forward 90 degrees, his horizontal semicircular canal will signal counter-clockwise velocity and his vertical semicircular canal will indicate clockwise velocity (20:230).

(Figure 2) turns his head quickly, he will experience spacial disorientation (Figure 3). Repetition of this stimulus will almost invariably evoke symptoms of motion sickness. This can occur frequently when a pilot moves his head in high-G maneuvers. The most common occurences of motion sickness include air, sea, and car sickness and is usually characterized by a pale complexion, cold sweating, nausea, drowsiness, and vomiting (27:1075). There appears to be two kinds of sensory derangement responsible for motion sickness. One is the inter-modality conflict, primarily between the eyes and the vestibular receptors. The other is an intra-modality or intra-labyrinthine conflict between the semicircular canals and the otolith organ (25:26).

Since all of these senses are potentially involved either directly or indirectly (as in the case of the vestibular system during visually-induced sickness), in the motion perceptions that cause sickness, it becomes pointless to ask which of them - canals, otoliths, eyes, or non-vestibular proprioceptors are the prime offenders (25:26). The one common factor in all of the sickness provoking situations is not the predominance of either linear or angular accelerations, but rather the presence of sensory rearrangement in which the inputs to the vestibular receptors are artificially distorted to render them incompatible either with each other, or with the eyes, or both (25:26).

The study of motion sickness is important to the Air Force because there is a high incidence of motion sickness experienced

by student pilots in their first phase of flight training. This malady eventually leads to a 2% attrition rate from pilot training and approximately a 40% attrition rate from navigator training (16:984). Additionaly, even veteran pilots are occasionally afflicted with this vestibular disorder which can inhibit mission success because of decreased flight performance (5:66;15:1).

Since the inception of manned spaceflight, motion sickness has affected as many as 50-80% of both space shuttle astronauts and Soviet cosmonauts (21:1148). Space motion sickness usually occurs during the initial 24-72 hours of orbital flight during vestibular adjustment in the weightless environment (23:601). Space motion sickness symptoms range from lethargy and loss of appetite to vomiting (23:601). Sensory conflict appears to be the basic mechanism underlying space motion sickness (23:604). During orbital flight, signals from the otolith receptors in the inner ear would conflict with those from the semicircular canals and the eyes (23:604). The cost of space motion sickness in lost working hours during a mission is immense (21:1148). The sheer expense associated with each manned space launch, the high task loading of spacecrew, and the relative irrevocability of each space mission once committed makes space sickness a hazard of primary importance. Furthermore, the consequences of an astronaut vomiting during extra-vehicular activity are potentially dangerous (23:601). Just in the Apollo program alone, 10 of 21 astronauts had suffered some kind of space

sickness. Symptoms ranged from mild sensations of tumbling to serious cases of prolonged nausea and vomiting. In the few months between Apollo 7 in October, 1968 and Apollo 13 in the spring of 1970, there were more recorded episodes of sickness than in all the preceeding seven years of manned flight (20:35). These instances are summarized in Table 1 below:

Table 1 Episodes of Space Sickness Among Apollo Astronauts

Mission	Nature of Symptoms
Apollo 7	Mild sensations of tumbling (1)*
Apollo 8	Stomach awareness, nausea and vomiting (3)
Apollo 9	Strong sensation of tumbling, anorexia, queasiness (2); persistent nausea and vomiting (1)
Apollo 10	Stomach awareness, anorexia, nausea (1)
Apollo 11	Mild anorexia (1)
Apollo 12	No reported symptoms
Apollo 13	Stomach awareness (2); nausea and vomiting (1)
Apollo 14	No reported symptoms

* number of crew members (20:35)

Past efforts aimed at relieving motion sickness have mainly included anti-nauseant drug treatment. However, these drugs were unreliable and carefully administered only during rehabilitation therapy in a non-operational setting since it has been held that any medication, or condition that requires medication, will diminish operational flying proficiency to a potentially

dangerous level (30:310;5:67). This claim is supported by the well known side effects of anti-nauseant or anti-motion sickness drugs, namely "dry mouth, dizziness, and drowsiness (30:311)." Air Force flight surgeons and the Federal Aviation Administration (FAA) maintain the position that the use of medication is prohibited for essential crew members during flight (30:316).

Current efforts have been directed towards designing and evaluating an effective drug free rehabilitation program. One such program was evaluated at the Brooks AFB School of Aerospace Medicine in Texas for student pilots as well as veteran fliers that were experiencing problems with air sickness (17:2). Training included desensitizing the individual to the forces experienced which seems to cause the airsickness. Because motion sickness is recognized as a stressful experience but one to which an individual can adapt, there had been hope in using biofeedback training (19:465). The subject was first stressed close to the point of experiencing motion sickness so that he could recognize the forewarning symptoms and apply relaxation techniques to bring his physiological reactions under control (17:2). As training progresses, the level of stress was increased and the subject was able to control his motion sickness in the operational environment (17:2).

This form of biofeedback training had proven successful in that approximately 84% of aircrew individuals have returned to operational flying status; however, Air Training Command (ATC) has encouraged the USAF School of Aerospace Medicine (SAM) to

develop a less expensive and more effective program suitable for use at flying training bases (15:1). Developing such a system requires a more accurate and effective means for measuring physiologic changes in an individual and must minimize the time the physician spends with the subject as well as eliminating the need for a technician in the treatment room (15:1). As currently implemented, "the desensitization treatment for each subject requires 20 hours of close supervision by a highly trained psychotherapist who titrates the level of stimulus to the psychotherapist's appraisal of the subject's motion discomfort (15:1)."

To date, research has not quantitatively identified those processes in the human body that can be measured objectively to establish values for predicting the onset of motion sickness (17:5). At the request of the USAF School of Aerospace Medicine, an apparatus was built at the Air Force Institute of Technology (AFIT) to collect a wide spectrum of data on human subjects in an effort to identify potential predictive parameters of motion sickness (15:1). The apparatus currently consists of a multiaxis motion simulator to evoke motion sickness symptoms in a subject and physiological monitoring equipment to measure the subject's consequent physiologic changes. Additionally, a computerized data acquisition system was developed during a previous thesis effort by Captains Douglas Fitzpatrick and Robin Williams in an attempt to reduce future manpower requirements in a biofeedback training session (11). With the current system configuration,

data collection is more efficient and flexible. This will allow more time and effort to be directed towards performing an in-depth statistical analysis on the data collected to identify potential parameters of motion sickness.

Problem

The purpose of this thesis project is to continue collecting biophysical data on human volunteers and then statistically analyze the data to determine if there is a relationship between motion sickness incidence and specific physiological measurements and if it is possible to identify the predictive parameters of motion sickness.

Scope

This thesis project will be limited to:

1) relocating the multiaxis motion simulator to building 640 room 150;

2) collecting biophysical data from human volunteers using a multiaxis motion simulator to elicit a motion sickness response;

3) incorporating parallel paper strip-chart recorders for real-time hard copy output;

4) performing a statistical analysis on the data collected to see if there are predictive relationships between the physiological measurements. Analysis techniques that will be considered are:

a. time variations in statistical parameters such as

mean and standard deviations of the data samples compared to baseline values;

b. spectral analysis techniques to evaluate differences in the frequency spectra;

c. multivariate statistical techniques to evaluate interrelationships between variables;

5) interfacing with Captain Robert Miller and Captain Dana Hartle whose concurrent thesis efforts involve correlating all data regarding motion sickness.

Assumptions

In order to use certain statistical techniques, an assumption that must be made is that the dependent variables involved are of a continuous nature and that the variables are somewhat correlated. It is also assumed that the reader is somewhat familiar with basic statistic terminology. Finally, it is not the intention of this thesis project to identify or understand the specific causes of getting motion sick. Thus, it is immaterial if motion sickness is caused from psychological factors, somatic factors, or a combination of both.

Support Equipment and Materials

The equipment needed for this study is available through the Electrical Engineering Department and includes the following:

1) MASSCOMP MC500 minicomputer and appropriate peripheral units.

2) A multiaxis motion simulator (hereafter referred to as the chair).

3) Three 6 channel strip chart recorders (Brush Mark 260 recorders).

4) Kyowa Dengyo 14 channel Beta tape recorder.

5) Various physiological sensors developed by Dr. Czelen including:

a. electrocardiogram

b. thermistor to measure skin surface temperature

c. electronastagmogram to measure eye movement

d. galvanic skin reflex to measure resistivity

e. photo-plethysmographs to measure pallor

f. electrogastrogram to measure gastric motility

g. electrointestinogram to measure intestinal tone

h. pneumographs to measure respiration rate

i. ballistocardiogram to measure heart rebound

j. electroencephalogram to measure brain wave activity

6) Hewlett-Packard 3582A Spectrum Analyzer.

Approach

The approach taken includes the following steps:

1) A literature search was performed by reading past theses, correspondence from the School of Aerospace Medicine, documentation of the BDAS program, documentation about the MASSCOMP computer, previous books and articles on the subject of motion sickness, and books about techniques regarding multivariate statistical analysis.

2) Relocating the multiaxis motion simulator from building 470 to building 640 in order to better control environmental conditions.

3) A continuing effort to improve the physiological monitoring equipment.

4) Standardizing testing procedures and protocols.

5) Data collection from volunteers.

6) Statistical analysis on the data collected.

Order of Presentation

Chapter 2 is a summary of past efforts to quantify parameters and estimators of motion sickness. Chapter 3 is the methodology of this thesis project. It includes the theory and procedures taken to statistically analyze subject data. Chapter 4 is a further analysis with implication on modeling motion sickness and Chapter 5 contains conclusions and results of the experiment and provides recommendations for further research in this area.

II Historical Perspective

Air Force Direction

The Air Force Institute of Technology (AFIT) was requested by letter in February 1982 from the School of Aerospace Medicine (SAM), Brooks AFB, TX to provide technical assistance in developing a system for treatment of airsickness using biofeedback techniques. Specifically SAM envisioned a system that would be cost effective and suitable for use at flying training bases (13:2). The system should be suited to collect up to 16 independent channels of physiological data on a subject. The system would be capable of inducing Coriolis stimulation on the subject by varying the speed of chair rotation and timing head tilts based on an experimenter's appraisal of motion susceptibility and ultimately feed back to the subject predictions of their physiological motion discomfort by some visual cue as well as a variable pitched sound (13:3). In a simplistic sense, SAM wanted to automate the existing motion sickness rehabilitation program implemented at Brooks AFB, TX by using physiological monitoring equipment that was computer controlled and required only one technician.

Prior AFIT Theses

In response to the SAM request, Captains Earl and Peterson in 1983, constructed a Biophysical Data Acquisition System (BDAS) consisting of a rotating motion simulator (the chair), a CIM-800 microcomputer, various physiological monitoring devices, and a

MASSCOMP MC500 data acquisition computer (9:1-2). Physiological monitoring equipment to measure heart rate, gastric motility, respiration rate, and skin pallor were designed and built. Commercially available sensors were also used and included devices to measure skin surface temperature, galvanic skin reflex (GSR), and electromyogram (EMG) of superficial muscles (9:vii).

Next, Captains Fitzpatrick, Rogers and Williams in 1984, developed a user friendly BDAS computer program to process the multiple channels of biophysical information that included data storage as well as graphical display. Also, amplifier circuits that transmit the physiological signals used to measure heart rate, gastric motility, respiration rate, skin pallor, intestinal tone, and eye movement were documented. They also used commercially available equipment including a thermometer, myograph and dermograph (11).

In 1985, Captains Jarvis and Uyeda concentrated mainly on refining the BDAS program and collecting subject data. However, they experienced considerable trouble with the MASSCOMP MC500 hardware due mainly to the malevolent environmental conditions of building 470 (excessive humidity, no air conditioning in the summer and no heat in the winter). Also, an effective head motion protocol had not been established to elicit effective motion sickness symptoms in the subject. Finally, initial data collected could not be statistically analyzed due to the small sample size and non- uniformity of the data itself. However, basic trends between groups of data were identified. For

example, they found that as a subject becomes motion sick, stomach awarness and galvanic skin reflex showed the same trend by sudden increase in both EGG and GSR readings (17:81). Also, they elected not to use EKG, peripheral photoplethysmograph, EMG, and ballistocardiogram because of the questionable value of the information provided by their sensing and recording system.

Current AFIT Theses

This thesis effort intended to continue collecting subject data and then statistically analyze that data. However, during the experiments, the decision was made to relocate the chair and peripheral equipment to building 640 in order to assure better control over environmental conditions for both the test subjects and the MASSCOMP MC500 computer.

System Hardware

The current hardware configuration of the biophysical data acquisition system can be seen in Figure 4. The multiaxis motion simulator was constrained to rotate only about the vertical axis (planetary yaw). A hardware improvement over the prior theses came in the form of a Kyowa Dengyo 14-Channel Beta recorder. Also, modifications to physiological sensors placement were made. The following is a list of all the physiological sensors used to collect subject data:

1) A - Electroencephalogram / EEG (frontal)
   B - Electroencephalogram / EEG (frontal)
   C - Electroencephalogram / EEG (occipital)

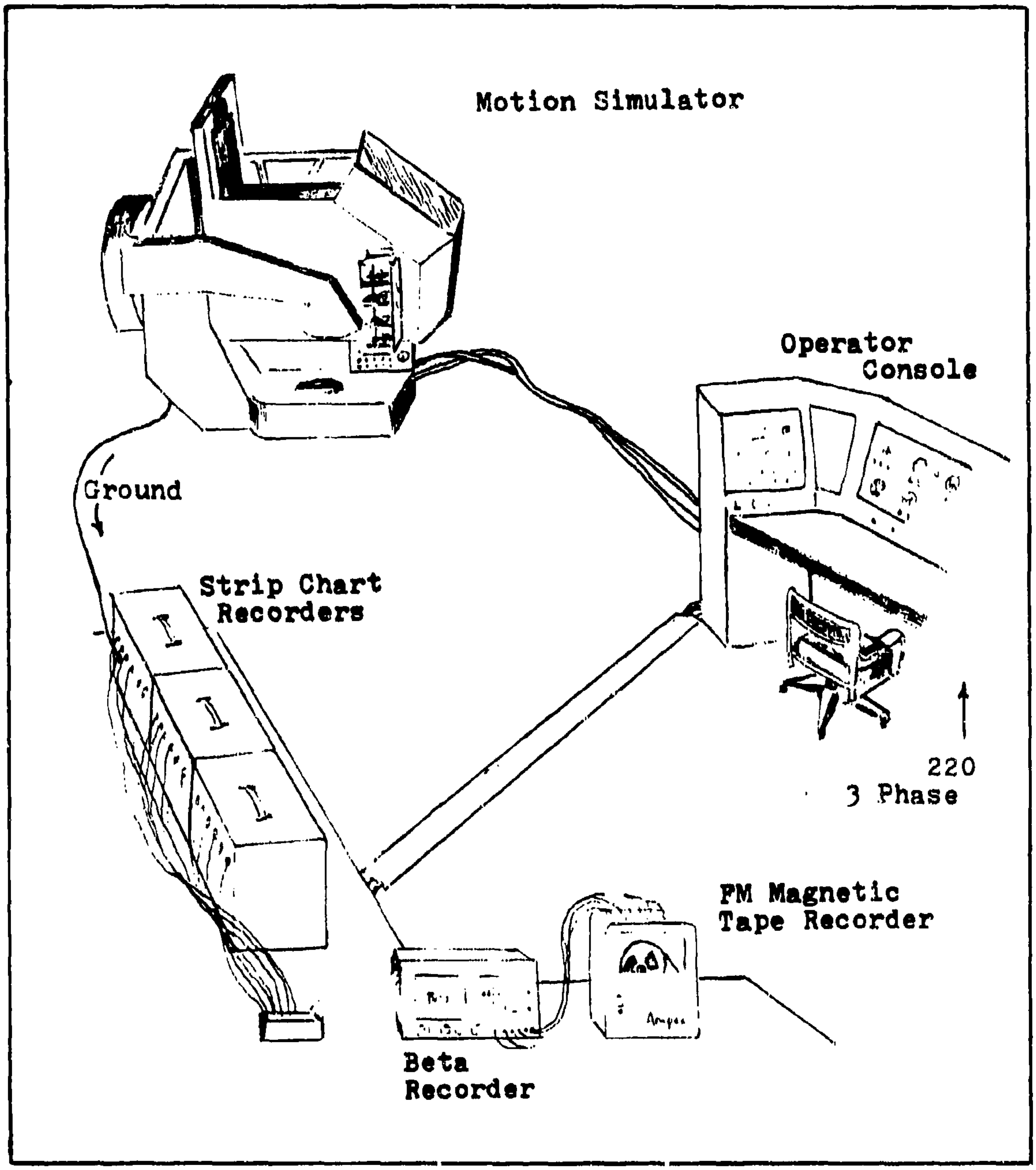


Figure 4 Current System Configuration

2) Photo - plethysmograph (facial)

3) A - Electronystagmogram / ENG (vertical)

B - Electronystagmogram / ENG (horizontal)

4) Electrocardiogram / EKG (vector)

5) Electrogastogram / EGG (left upper quadrant)

6) Electrointestinogram / EIG

7) EGG/EIG Common

8) Thoracic Respiration and Ballistocardiogram

9) Diaphragmatic Respiration

10) Blood Pressure and Pulse

11) Galvanic Skin Reflex (GSR)

12) Photo - plethysmograph (finger)

13) Thermistor (surface skin temperature)

14) FM microphone (subject input)

The placement of the above sensors can be seen in Figures 5 and 6 on the following pages. Explanation for the use of individual sensors can be found in the Jarvis and Uyeda thesis (17).

Hardware Problems

A good deal of time and effort was consumed during the move. Once the chair was disassembled, it was evident that new spacers and bearings were required for smooth 360^{o} rotation. The main bearing plate also needed to be recut and nickel plated. Upon reassembling the chair in building 640, some additional obstacles appeared. For example, it was necessary to construct a carpenter's 3 ton A-frame to raise and move the chair to its new

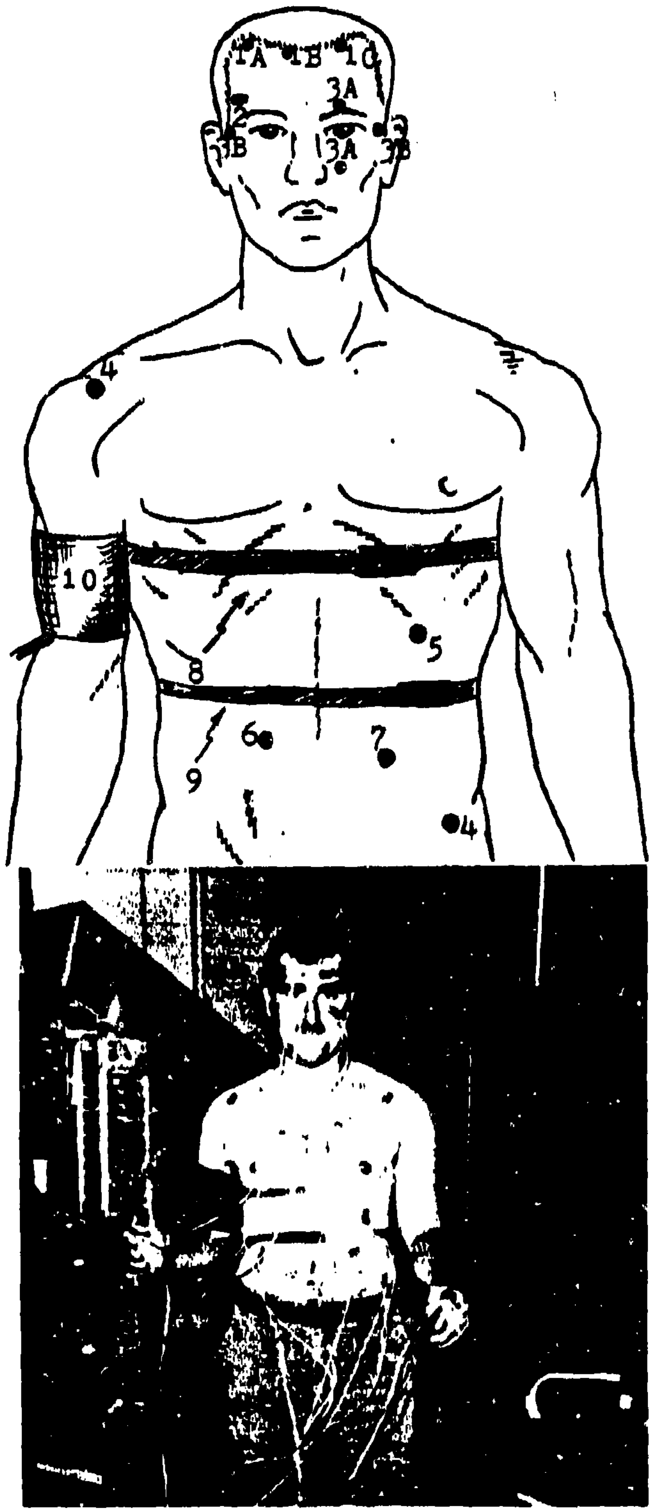


Figure 5 Sensor Placement (Central)

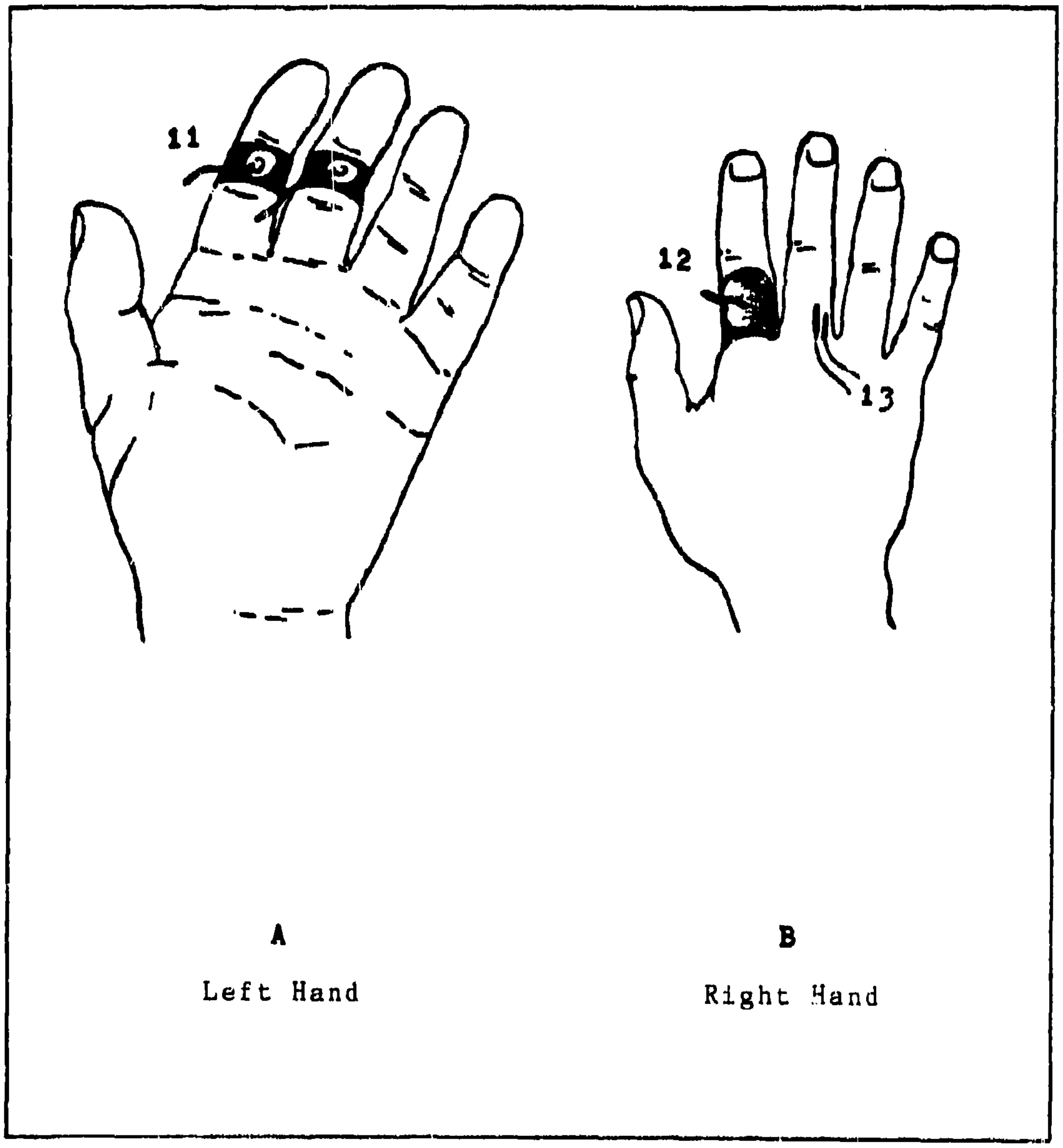


Figure 6 Sensor Placement (Peripheral)

platform. Another time consuming task included wiring the proper power to the console (three-phase 220 volts) and repairing an inoperative 15 volt power supply. Upon successfully completing these tasks, testing the equipment began. The only other obstacle encountered was a ground loop which introduced considerable noise into the system. The problem was rectified by carefully grounding the motion simulator via the slip rings to the recording equipment.

Hardware Changes

Minor changes to some of the physiological sensors were made and new calibration techniques were employed. Establishing a numerical reference point to calibrate the sensors was essential since past data collection resulted in only percent of estimated baseline changes rather than quantifiable units. For example, skin temperature is now measured in degrees Farenheit rather than plus or minus a percent of the individuals estimated baseline. Temperature is measured via thermistors taped to a finger on the subject's right hand (see Figure 6) and is recorded using commercial Autogen equipment.

Likewise, skin pallor, which was a very subjective measurement in the past, is now quantifiably measured by first totally exanguinating the subject's forearm with an Esmarch bandage and blood pressure cuff and then calibrating both the finger and facial photo-plethysmograph for complete pallor (See Figure 7a). The cuff is removed and the immediate blood flow into the arm represents a complete flush which also equates to an

A- 100 percent Pallor

B- 100 percent Flush

Figure 7 Skin Pallor Calibration

absence of pallor (See Figure 7b). Thus the two extremes of the scale are found for each subject before the test run begins. The data collected during the experiment can be represented as a percentage of total pallor.

The galvanic skin reflex (GSR) is a measure of subject surface resistivity (sweating). A scale of varying resistances from 10K to 1.5M resistance is used to calibrate the GSR instrumentation. This covers the subject's range of possible resistivity. Previously collected data only indicated a percent of the variation in the subject's baseline. Now, actual resistance values may be acquired.

Finally, both thoracic and diaphramatic respiration are calibrated using a commercially obtained spirometer (See Figure 8). The spirometer is placed in the subject's mouth and the subject is instructed to make a series of normal breaths. The spirometer measures the volume of air in cubic centimeters. As the subject breathes into the spirometer, the values in cubic centimeters are annotated simultaneously on the respiration strip chart recording.

System Software

The BDAS computer program is hosted on the MASSCOMP MC500 computer. Since the MASSCOMP MC500 hardware problems were not corrected until mid 1986, data reduction was performed by 1) manually sampling the hardcopy output from the strip chart recorders and 2) replaying edited tape through a spectrum analyzer. Thus the BDAS program was not used to collect real-

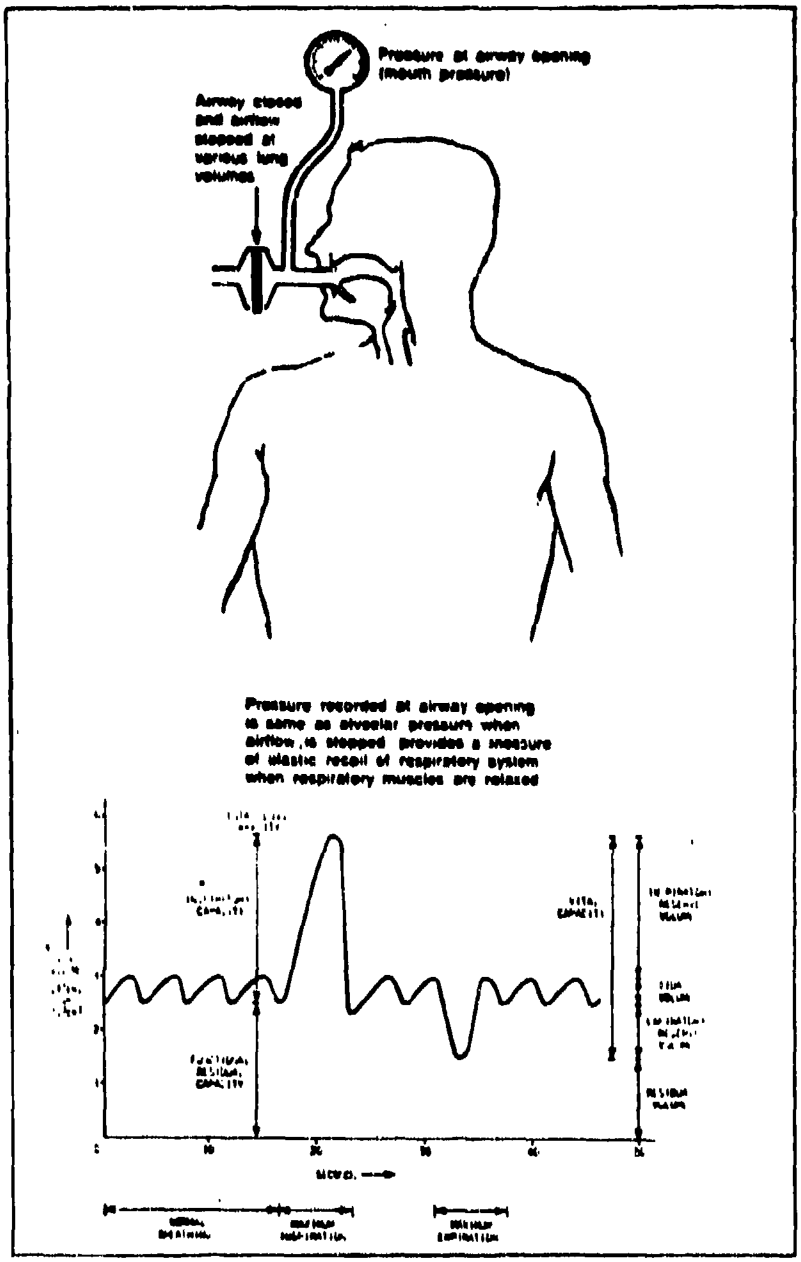


Figure 8 Thoracic Respiration Calibration Using Spirometer to Measure Volume (Cubic Centimeters)

time subject data. However, the MASSCOMP MC500 was used to analyze the manually obtained subject data. A statistical package called "S" was the primary software program used.

Once room 150 in building 640 is air conditioned, the MASSCOMP MC500 will be colocated with the motion simulator and facilitate direct real-time data acquisition and storage. Until then, the subject data will be collected on Beta tape and strip chart recorders.

Possible System Errors

A discussion of the errors that may be introduced by a typical data acquisition system is relevant since such errors must be known when analyzing the final data output. Figure 9 shows a hypothetical data acquisition system. The transducer produces a voltage proportional to the function being observed (10:26). The limiter in the figure symbolize the fact that there are definite limits to the magnitude of the voltage which the data acquisition system will pass (10:27). Some error is introduced in the form of noise. The noise may be either correlated or uncorrelated with the data. Next the data are digitized and the the analog to digital conversion also introduces a type of noise into the data known as quantization noise shown by Figure 10 (10:30).

There are other sources of noise. In summary:

1. Capacitive coupling exists between the human body and AC power systems. For instance, even the proximity of the subject to a metal chair, which probably picks

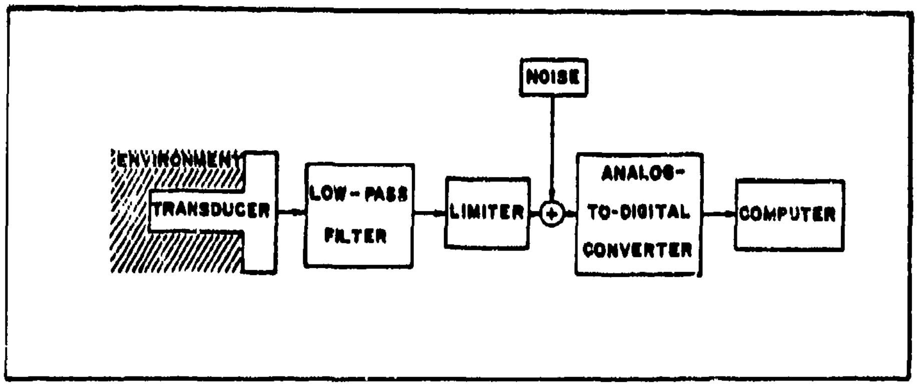


Figure 9 Hypothetical Data Acquisition System (6:26)

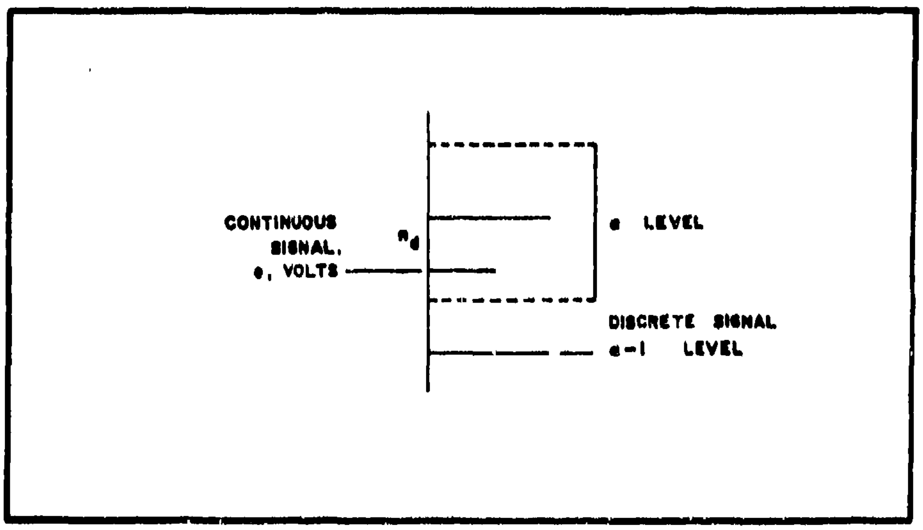


Figure 10 Quantization Noise in a Data Acquisition System (6:30).

up power line signals itself, forms a capacitive coupling and affects stray 60 Hz skin pickup. Because of the complexity of the 60 Hz noise source, it is almost impossible to avoid power line pickup by the human body except in carefully shielded and insulated environments (6:578).

2) Electrode noise results from the action of the electrode and the skin of the subject. The most effective way to reduce electrode noise is in properly designing the electrodes themselves by using high input impedence amplifiers that minimize the effects of variations in the electrode's impedence (6:580).

3) Random noise can occur due to biological artifacts, such as involuntary subject movements and muscle contractions picked up by the sensors and leads. Depending on the frequency characteristics of the desired signal and noise, high or low pass filters can be used to reduce the noise (6:580).

III Data Analysis

Introduction

This chapter outlines the approach taken to analyze the subject data collected using standard experimental testing procedures. Data on each of the physiologic parameters were collected both in the form of 1) a hard copy output on a strip chart listing and 2) recorded signals on magnetic tape.

Although only 12 subjects were used in the database, an extremely large amount of data was collected. Only subjects considered susceptible were used in the database. Data were used only from the most recent 12 subjects and not from prior theses effort since testing procedures and head motion protocol had not been fully standardized. Current data were collected in a uniform fashion using a standardized protocol. The majority of the data was reduced by manually measuring the tracings from the strip chart recorder outputs. The remainder was done through Discrete Fourier Transform (DFT) Spectral Analysis.

The channels of subject data must be analyzed using techniques appropriate to the nature of their signals. For example, to assure meaningful results, surface skin temperature, GSR, and finger and facial photo-plethysmographs will be analyzed using descriptive statistics while EEG, EGG and EIG will be analyzed solely using spectral density techniques. However, EKG and thoracic and diaphramatic respiration will be analyzed using both spectral density and descriptive statistical methods. Other collected parameters were not analyzed because their importance

has not yet been well established.

Theory

Multivariate statistics are an amenable way to handle situations where a number of variables are involved either as predictors or as measures of performance (14:5). For example, stimulating a subject up through the range of motion sickness may affect many somewhat different but partially correlated physiological parameters. Similarly, many different parameters of motion sickness may be of value in predicting the onset of motion sickness and it is necessary to consider how to combine all these pieces of information into a single best prediction of motion sickness (14:5).

In order to develop a worthwhile analysis of the subject data, it is necessary to identify those predictive relationships that may be of value. For example, one relationship might be that: given the independent varible called motion sickness, predict the effects on the dependent output variables (i.e. the various measurable physiological channels). Another useful relationship might be: tell what motion sickness symptoms the subject is experiencing by looking at the physiological channels being monitored and ultimately provide the subject with feedback to help him control his malaise. These relationships may be defined by building a table of the various physiologic parameters and the corresponding statistics obtained during specified phases of motion stimulus. This may give insight into structurally defining the motion sickness syndrome. These relationships may

then be used to predict the effect on a subject's measurable physiological parameters as he becomes motion sick and consequently suggest corrective actions through some feedback method to help the subject control and eventually overcome his motion sick condition. A basic model of this process may be graphically summarized as follows:

```
   INPUT                PROCESS            OUTPUT

stimulus ---------> subject ---------> motion sickness --
                       ^                                 |
                       ------ feedback <------------------
```

Figure 11   Basic Motion Sickness Model

Data Collection

In order to conduct valid experimental testing using human volunteers as outlined in AFR 169-3, a research protocol was written and submitted to the Human Use Resource Committee (HURC) for approval (see Appendix A). Since human volunteers are needed to collect data, this research protocol must be submitted to the HURC annually for approval.

Data collection began by giving subjects a series of questionaires to complete before each experiment (see Appendix C Jarvis and Uyeda Thesis). Only those subjects who were considered susceptible to motion sickness were used in the

experiments. Once a subject was selected, he was briefed on the procedural aspects of the experiment. Physiological electrodes were then attached to the subject as previously described in Chapter Two. The equipment was calibrated and one minute of control data was collected. The subject was seated in the chair and blindfolded. Subjects were briefed on specific head motions to make as directed by an on-board tape recorder. Data on each subject were recorded using three 6-channel strip chart recorders, a 14-channel Beta recorder, and a 14-channel backup Ampex magnetic tape recorder. The data were collected continuously throughout the experiment until one minute after the chair stopped or until the subject's physiologic signals returned to those approximating the control period. Data were originally collected on 12 subjects (see Appendix B). Data on one additional subject were later added to the data set and included only in the spectral analysis.

Descriptive Statistical Analysis

Because of the nature of their strip chart trace, surface skin temperature, pallor, respiration, EKG and GSR are amenable to descriptive statistical analysis.

In order to facilitate using descriptive statistics, each physiologic parameter taken from the strip chart recordings was sampled at 10 second increments over a range of five intervals. The intervals consist of 1) control interval, 2) symptom 0-3 interval, 3) symptom 4-7 interval, 4) symptom 8-10 interval, and

5) post interval. The five different intervals were chosen based upon common groups of symptoms encountered during each test run. This was done to standardize the number of divisions of each run into five specific time periods. The interval numbers correspond to a scale reported by the subject. The subject reports his subjective condition in the form of a numerical scale. The subject is queried every minute for a number from one to ten (one means no symptoms, ten means vomiting).

The control interval was selected as a baseline period for each subject. The symptom 1-3 interval was characterized by a general sense of well being and some slight discomfort. The symptom 4-7 interval consisted of symptoms ranging from dizziness and slight disorientation to sweating and mild stomach awareness. symptom 8-10 interval was characterized by heavy stomach churning, extreme dizziness, headaches, and nausea. Finally, the post interval consisted of the subject returning to near baseline conditions after the stopping of head motions.

The subject data can be analyzed by first estimating the arithmetic mean and standard deviation of the sample population for each physiological channel over each of the five ranges identified above. Each sample mean value is then an indication of the specific physiologic parameter value at a particular phase of motion sickness. Table 2 shows the estimated mean and standard deviation for each parameter over the entire experimental run. This sample data can allow one to make inferences about the entire population assuming, of course, that

the population from which the sample is drawn has a normal distribution. Since the estimate of each of the means is based on a small sample, it is necessary to determine a confidence interval that will indicate how far off the estimate might be from the actual population statistic.

Table 2 Estimated Motion Sickness Parameter Values

Parameter		Control	1-3	4-7	8-10	Post
Temperature	x=	90.5	90.9	89.3	90.3	91.4
	sd=	5.4	5.2	5.4	5.0	5.2
Facial	x=	54.2	60.2	73.0	73.3	65.6
	sd=	18.9	18.6	15.5	29.3	29.9
Finger	x=	74.5	77.8	73.6	66.1	57.6
	sd=	10.8	8.8	11.9	15.9	15.5
Thoracic	x=	539.3	569.1	700.7	824.7	829.4
	sd=	166.4	182.4	202.6	332.2	284.7
Diaphragm	x=	501.4	585.1	679.4	692.8	664.6
	sd=	391.0	334.9	345.3	443.9	423.3
EKG	x=	79.8	89.2	95.8	90.4	79.1
	sd=	17.2	19.2	19.4	19.2	15.6
GSR	x=	673.9	610.3	628.7	585.8	688.5
	sd=	435.9	329.4	291.9	291.5	190.8
#Breaths	x=	2.9	3.5	3.2	3.0	2.1
	sd=	0.6	0.8	1.2	1.5	0.5

A commonly used method to compute a confidence interval is Student's t-test (7:320). The equation is:

$$\bar{x} - 1.96 (s/ \sqrt{n}) < u < \bar{x} + 1.96 (s/ \sqrt{n})$$

where x is the estimated sample mean, sd is the sample standard deviation, u is the actual population mean, and n is the sample size (7:320). Table 3 displays the confidence intervals for each motion sickness parameter. It should be noted that subject data for GSR were from only two subjects and thus does not contain as large a number of sample points as the other parameters.

The parameters selected for analysis by means of descriptive statistics may be represented graphically by the figures on the following pages.

Table 3 Confidence Intervals

Parameter	Phase	Confidence Interval
Temperature	Control	89.24 to 91.77
	Sx 1-3	90.16 to 91.64
	Sx 4-7	88.03 to 90.57
	Sx 8-10	89.22 to 91.38
	Post	90.66 to 92.14
Facial Pallor	Control	44.94 to 63.46
	Sx 1-3	55.38 to 65.02
	Sx 4-7	63.39 to 82.61
	Sx 8-10	61.33 to 85.27
	Post	57.64 to 73.58
Finger Pallor	Control	71.97 to 77.03
	Sx 1-3	76.55 to 79.05
	Sx 4-7	70.79 to 76.41
	Sx 8-10	62.68 to 69.52
	Post	55.41 to 59.79
Thoracic Resp.	Control	500.32 to 578.28
	Sx 1-3	543.23 to 594.97
	Sx 4-7	652.90 to 748.50
	Sx 8-10	753.23 to 896.17
	Post	789.13 to 869.67
Diaphramatic	Control	409.81 to 592.99
	Sx 1-3	537.60 to 632.60
	Sx 4-7	597.93 to 760.87
	Sx 8-10	597.30 to 788.30
	Post	604.72 to 724.48
EKG	Control	75.77 to 83.83
	Sx 1-3	86.48 to 91.92
	Sx 4-7	91.22 to 100.38
	Sx 8-10	86.27 to 94.53
	Post	76.89 to 81.31
GSR	Control	567.11 to 780.69
	Sx 1-3	561.05 to 659.55
	Sx 4-7	557.72 to 699.68
	Sx 8-10	520.28 to 651.32
	Post	660.23 to 716.77
#Breaths	Control	2.74 to 3.04
	Sx 1-3	3.37 to 3.61
	Sx 4-7	2.93 to 3.51
	Sx 8-10	2.70 to 3.34
	Post	2.06 to 2.18

Galvanic Skin Reflex (GSR)

GSR mean values during each phase show an overall decrease in subject resistivity from Control interval to symptoms 8-10 interval. This equates to a change in skin conductivity. Increasing conductivity in a subject is closely associated with sweating on the subject's skin. Upon stopping head motions (post interval), the subject's resistivity increases to approximately that of the control interval.

Surface Skin Temperature

In most cases, the subject's skin temperature, which is measured on the finger, decreased during pre-nauseating symptoms (symptom 4-7 interval) and then increased well after stopping head motions. The decrease in temperature may be due to the subject's sweating coupled with effects of surface cooling. Caution should be taken in accepting this finding since the experiment was run under less than perfect environmental conditions. After reducing the data for this parameter, another temperature measuring device (thermistor) on the subject's face will be used to get a better indication of surface skin temperature.

Electrocardiogram

The EKG data indicate that as the subject experienced motion sickness symptoms, their heart rate increased 20% on the average. Once initial symptoms were attained, the heart rate returned to near control interval conditions. On one occasion

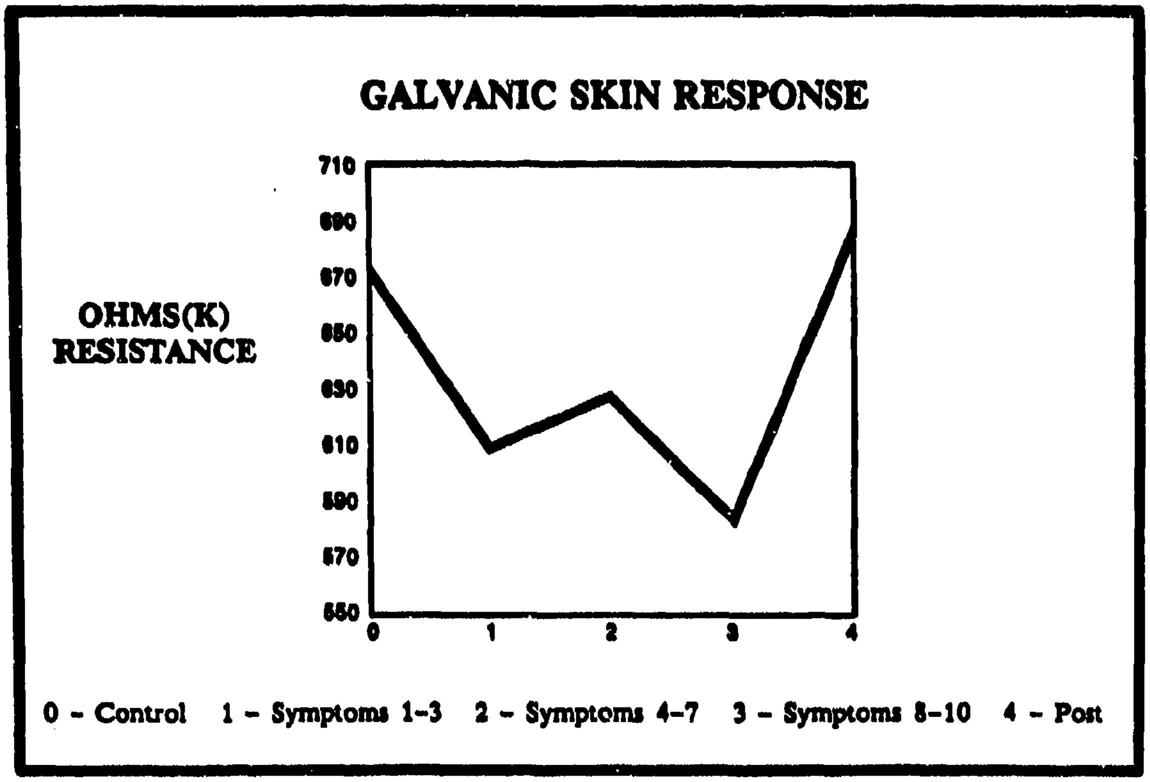


Figure 12

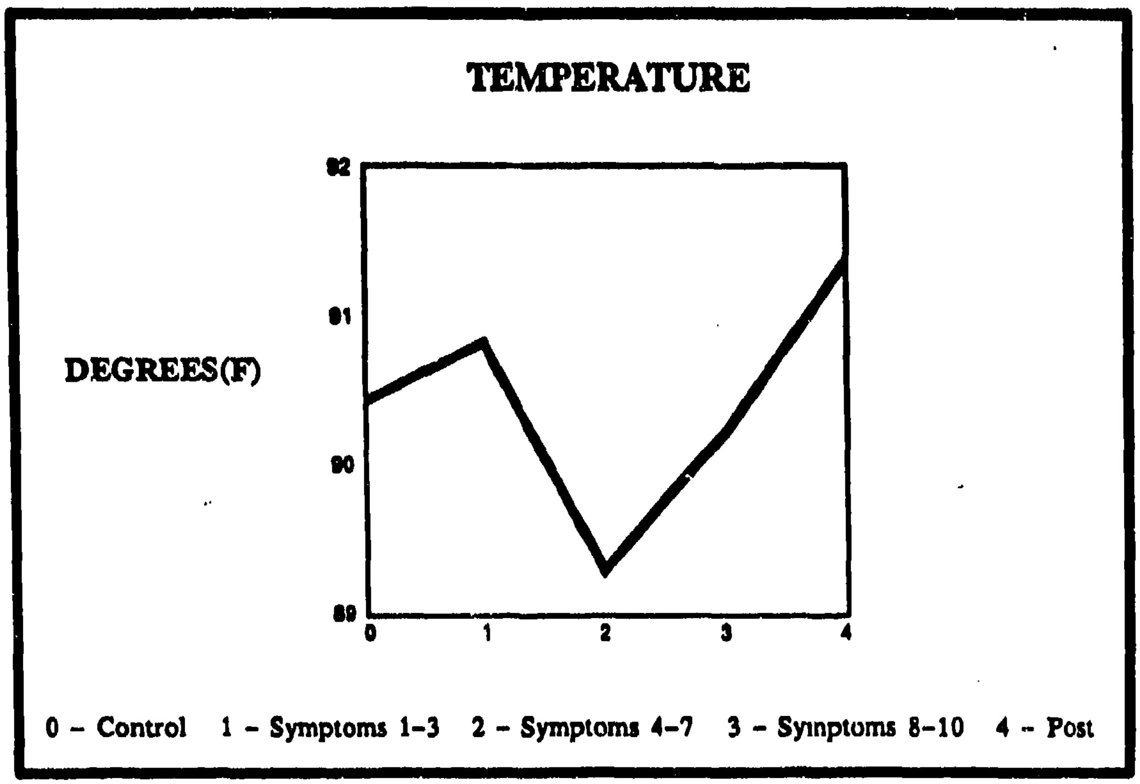


Figure 13

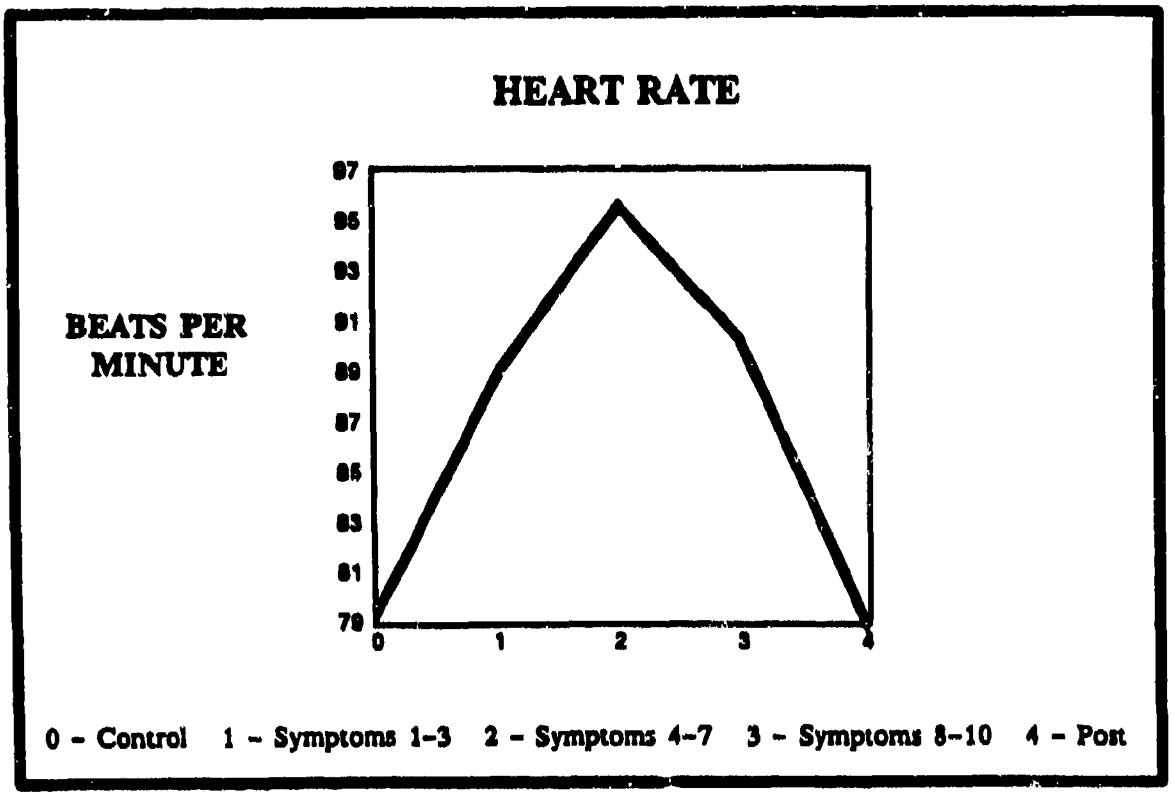

HEART RATE
BEATS PER MINUTE
97
95
93
91
89
87
85
83
81
79
0
1
2
3
4
0 - Control   1 - Symptoms 1-3   2 - Symptoms 4-7   3 - Symptoms 8-10   4 - Post

Figure 14

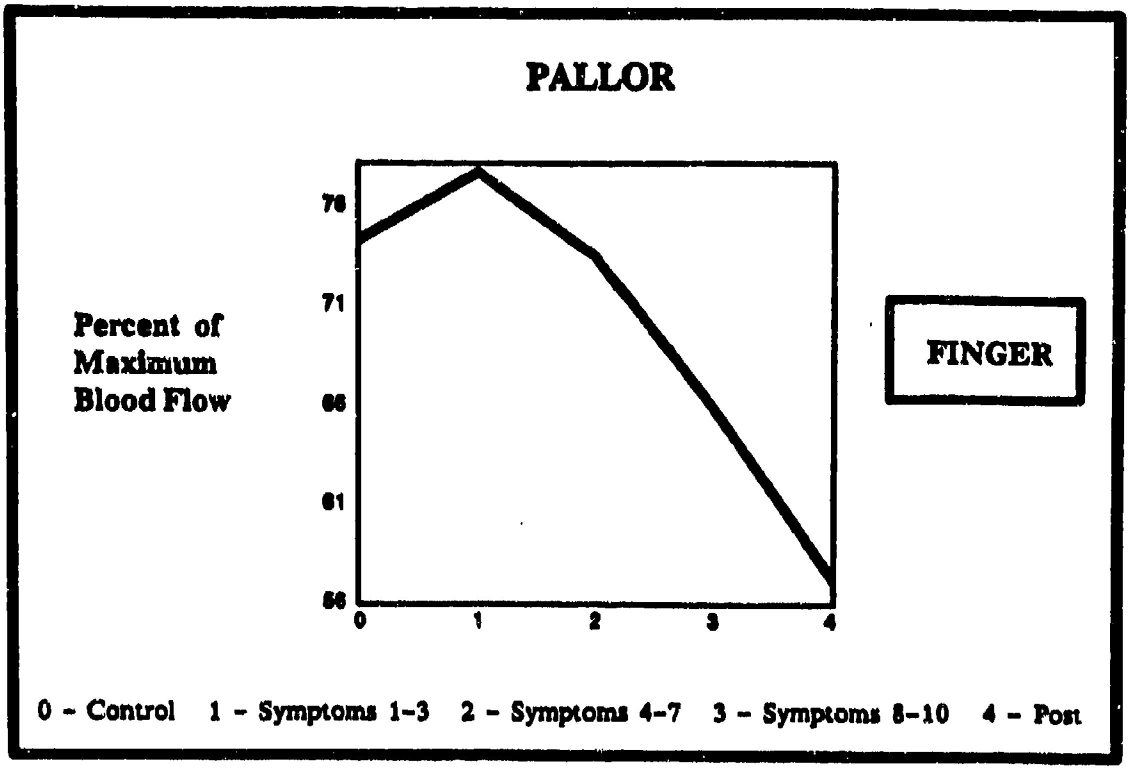


Figure 15

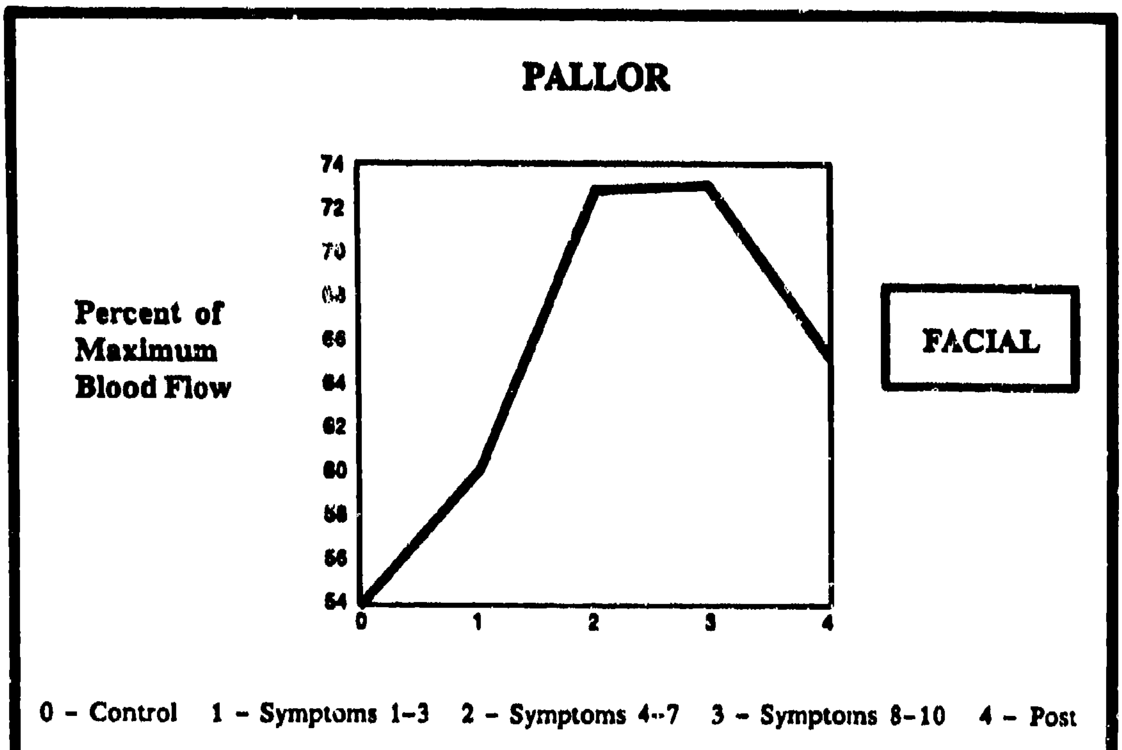


Figure 16

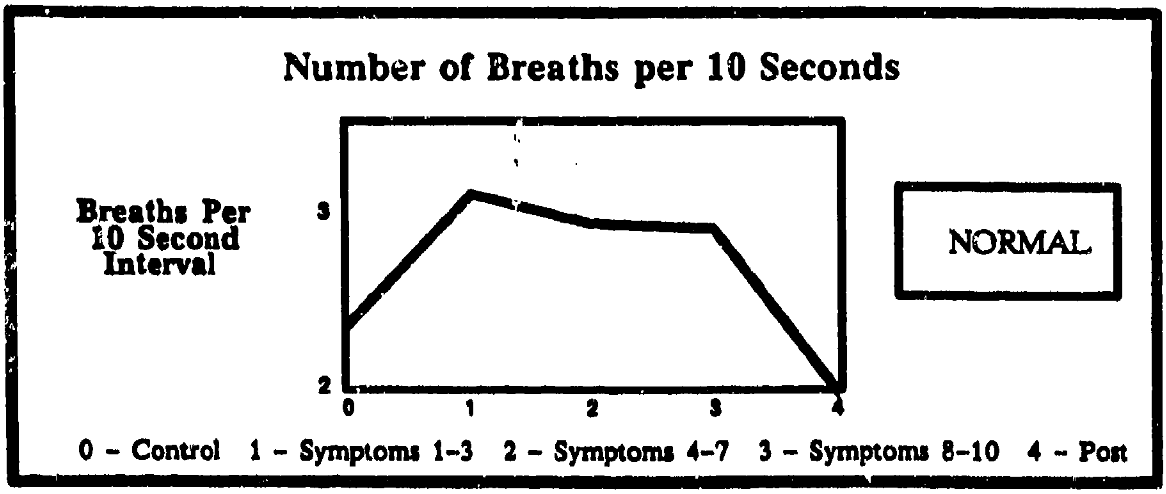


Figure 17

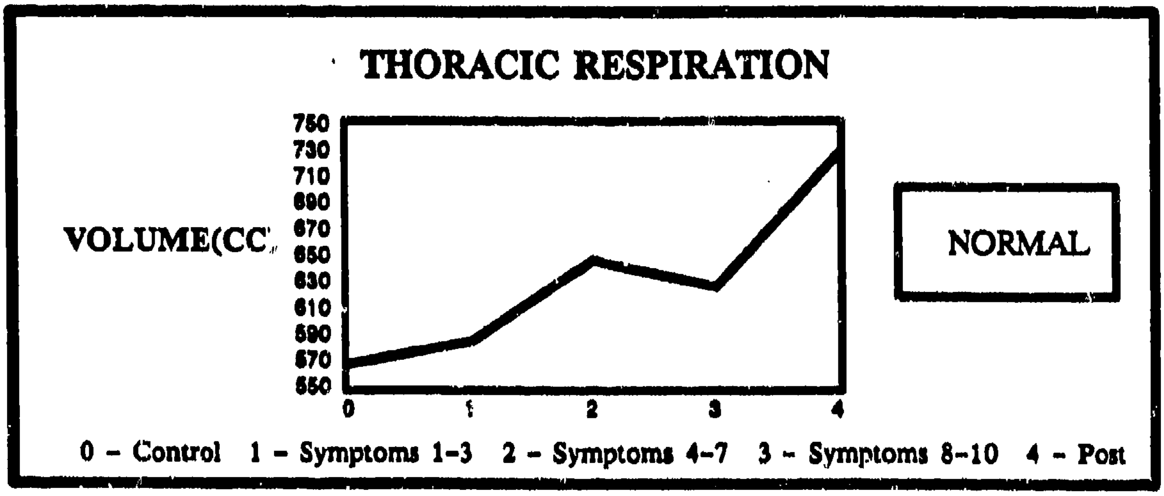


Figure 18

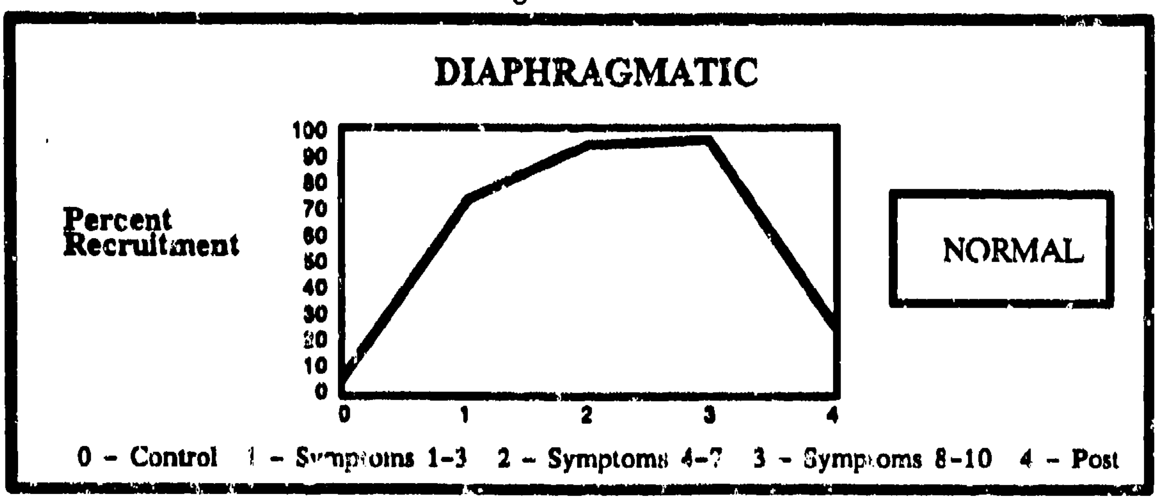


Figure 19

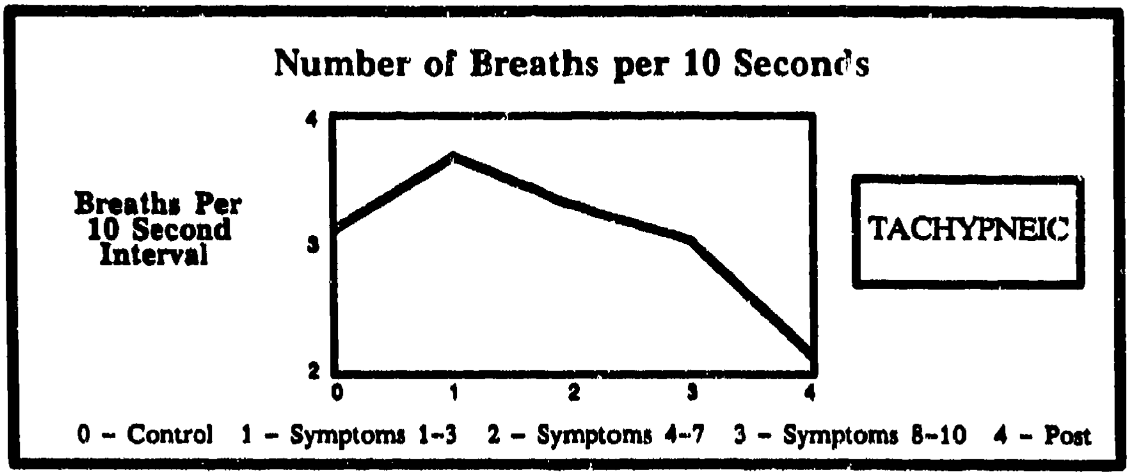
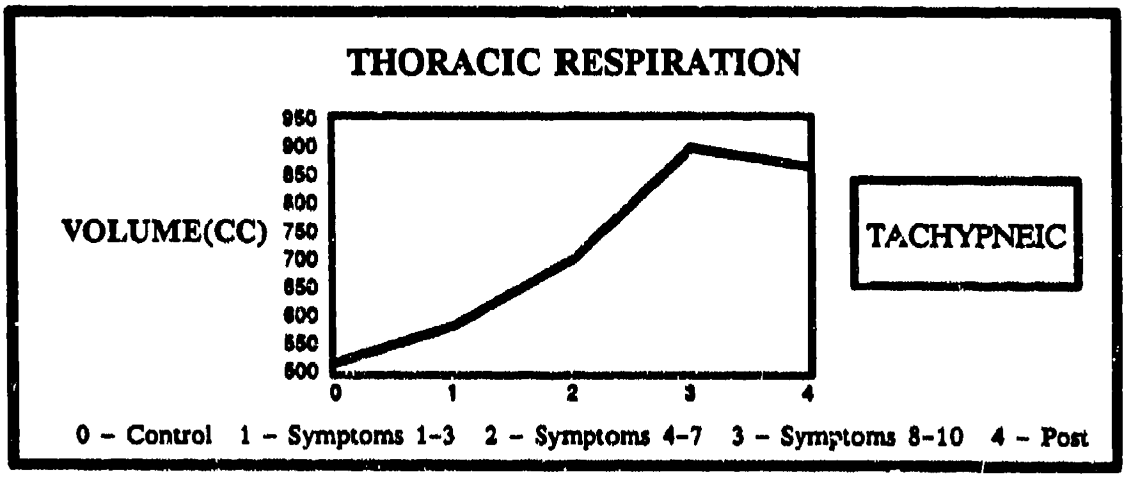


Figure 20



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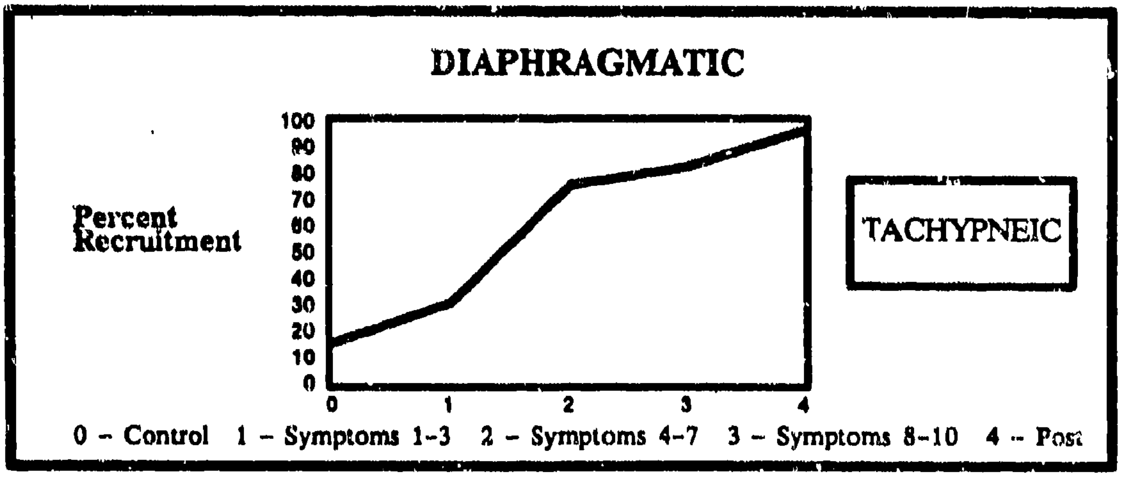


Figure 22

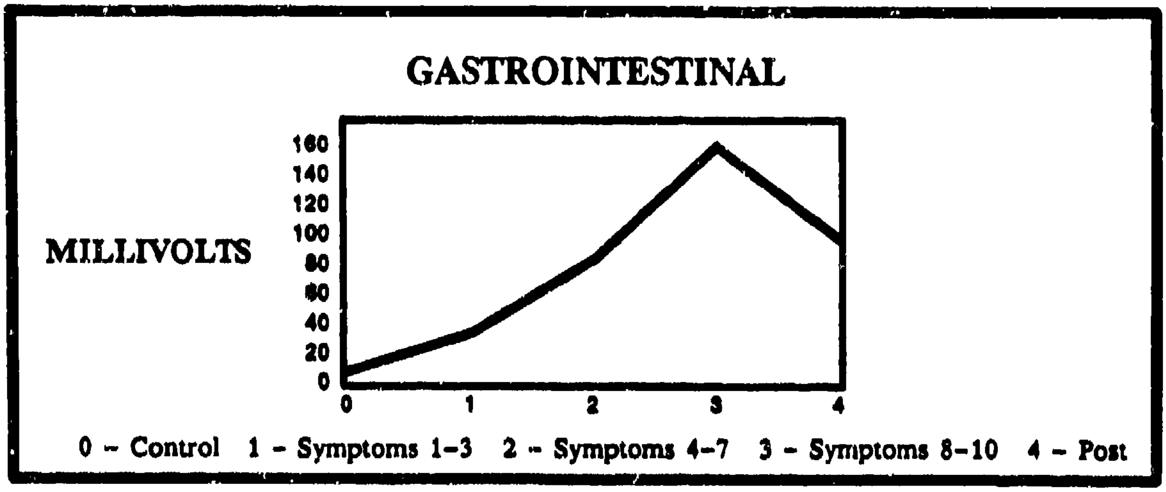


Figure 23

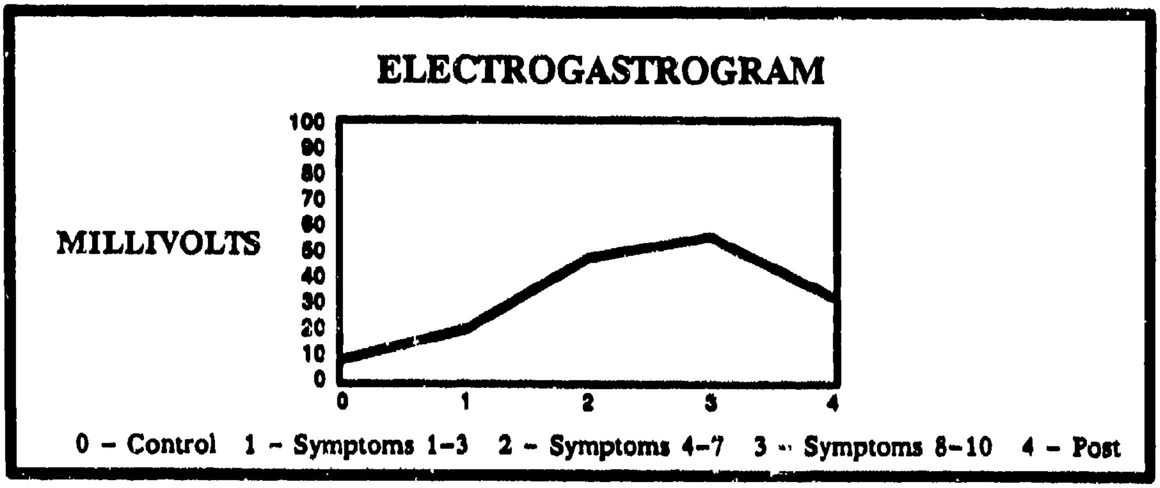


Figure 24

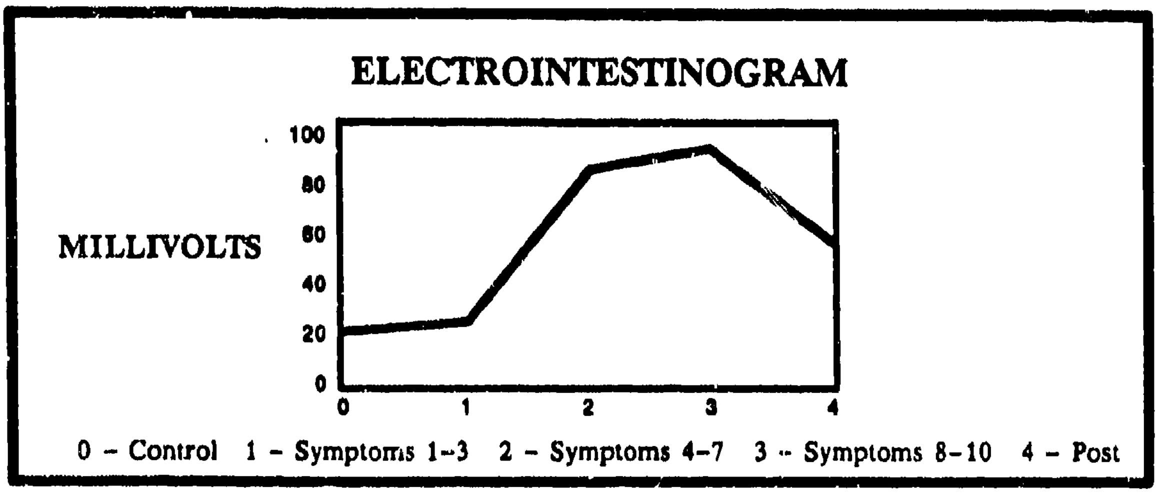


Figure 25

the subject passed the nausea stage (vomiting) and the subject's heart rate at that point doubled. It should also be noted that in three of the subjects, their heart rate fell to approximately 40 beats/min. These particular cases were classified as sinus arhythmia by Dr. Czelen and results will be further explained in his motion sickness study (to be published).

Pallor

Finger blood flow was found to decrease on the average and was indicated by an increase in pallor. This is supported by a visible confirmation of subject paleness as they progressed through the stages of motion sickness. However, facial blood flow did not indicate this same decreasing trend but instead showed a flush in the subject's skin color. This may be explained as an error or atypical response since only two subjects' data were used (because the sensor was under continual refinement). The finger pallor indication confirms that pallor increases in the majority of subjects and precedes the onset of severe motion sickness (17:87).

Respiration

From the data collected it can be clearly seen that, on the average, the typical subject's respiration volume increased from the control interval through symptoms 8-10 interval. It should be noted that subjects were classified in two ways. Subjects whose control interval respiration rate was less than or equal to 15 breaths/min, were classified as normal breathers.

Those whose control interval respiration rate exceeded 15 breaths/min, were classified as tachypneic. The dip in the graph of normal thoracic respiration is indicative of the weak confidence interval noted earlier in Table 3. For normal breathers the number of actual breaths taken also increased from 14 breaths/min to more than 18 breaths/min. For those who were tachypneic, the respiration rate decreased as symptoms progressed while volume of breaths increased. The data also suggest that there is a noticeable diaphragmatic contribution to respiration as the subject becomes motion sick. Caution in this conclusion should be exercised since diaphragmatic volume may not be linearly related with thoracic respiration as was assumed when the system was calibrated.

EGG and EIG

The data of the electrogastrogram and electrointestinogram as well as the combined EGG and EIG shown in the gastrointestinal graph merely represent mean amplitudes at each symptom interval. The major reason for doing this was to show that the subject's abdominal region showed increased activity during the onset of nausea.

Correlation Analysis

Although descriptive statistics present important characteristics of the sampled data, it would be very useful to determine whether the selected physiological parameters or if any others have a relationship among themselves, or more importantly,

to motion sickness. To accomplish this, a correlation analysis was performed.

A correlation analysis is a common method to measure the association between variables. Through the use of a statistical package called Microstat, a sample correlation matrix was calculated in which each element of the matrix is a correlation coefficient (r) between two variables. Each r value is a measure of how strongly related the variables are in a sample. The value of r lies between -1 and +1 and is equal to +1 only if all pairs of the two variables lie on a straight line with positive slope and $r = -1$ if all pairs lie on a straight line with a negative slope (7:449). Thus r measures the degree of linear relationship among variables. If r is near zero, it does not imply a lack of relationship but rather only an absence of a linear relation.

The relationship is described as strong if $r >= .8$, moderate if $.5 < r < .8$ and weak if $r <= .5$. A strong positive relationship suggests that a large value of one variable is paired with a large value of another variable. Table 4 shows the correlation matrix for the indicated parameters. It should be noted that the parameters diaphragmatic respiration and facial plethysmograph were not correlated. Diaphragmatic respiration was not used due to the uncertainty of the calibration and thus the usefulness of information. The facial plethysmograph data were not used since valid measurements were obtained only on two subjects.

The values of the correlation coefficient r indicate that

Table 4 Correlation of Motion Sickness Parameters

	Temp	Finger	Thoracic	EKG	GSR	Breath	Msick
Temp	1.0000						
sig	0.0000						
Finger	0.3127	1.0000					
sig	0.3833	0.0000					
Thoracic	-.5417	-.9097	1.0000				
sig	0.1058	0.0003	0.0000				
EKG	-.7641	-.2698	0.6421	1.0000			
sig	0.0100	0.4536	0.0451	0.0000			
GSR	0.1453	0.6088	-.7902	-.6399	1.0000		
sig	0.6886	0.0619	0.0065	0.0463	0.0000		
Breath	0.0669	0.6169	-.2811	0.4279	-.2324	1.0000	
sig	0.8151	0.0497	0.3929	0.2486	0.5644	0.0000	
Msick	-.4822	-.8980	0.9948	0.6405	-.8392	-.2298	1.0000
sig	0.1581	0.0004	0.0001	0.0459	0.0024	0.4753	0.0000

Note: sig is the significance value
Percent = (1 - sig)

finger pallor, thoracic respiration, and galvanic skin reflex are all strongly correlated to motion sickness while EKG is only moderately correlated. The significance values suggest that all three strongly correlated parameters are statistically significant. The significance values 0.0004, 0.0001, and 0.0024 correspond to finger, thoracic and GSR. One minus each of the significance values suggest the percent confidence in each corresponding correlation value. Thus, the parameter finger shows 99.96% confidence of being correlated to motion sickness in a linear relationship. Thoracic is 99.99% and GSR is 99.76% confidence bound.

Finger pallor shows a negative correlation (finger blood flow decreases as motion sickness symptoms become more severe) which supports the previous findings of Jarvis and Uyeda (17). Galvanic Skin Reflex also shows a negative correlation with motion sickness which supports previously stated claims that there is a decrease in the subject's resistivity as motion sickness symptoms increase. Thoracic respiration is positively correlated to motion sickness which corresponds to an increase in the amplitude of breaths as motion sickness symptoms increase. Finally, EKG shows positive correlation to motion sickness while surface skin temperature and breathing rate both show weak negative correlation.

Spectral Analysis

The remainder of the physiologic parameters were analyzed using a DFT Spectrum Analyzer. Spectral analysis is useful in

identifying amplitude changes in energy as well as frequency shifting between the five intervals. The graphs on the following pages were plotted using a Microcomputer software package called Lotus. Points to create the graphs were obtained by first performing a spectral analysis on each parameter at each interval and then using the built-in marker to extract data points. The resolution of the DFT Spectrum Analyzer allowed plotting points every .008 Hz. Thus each graph is a separate parameter shown over all five intervals. Mean frequencies for each parameter were also calculated over each interval.

Gastrointestinal

The gastrointestinal spectrum indicates the total stomach and intestinal response through the five intervals. It is clearly seen that there is a significant increase in energy which corresponds to the increase in amplitude as the subject approaches nausea (Sx 8-10). This increase in amplitude also indicates an increase in smooth muscle activity in the gut. The frequency data indicate that the EGG component is noticeable at 0.008 Hz and that the EIG component of the spectrum can be seen at approximately 0.16 Hz.

Electrointestinogram (EIG)

The EIG is a measure of small intestine activity. The basic electrical rhythm (BER) of the small intestine is approximately 11-12/min at the duodenum and decreases distally to the ileum where the frequency is 7-9/min (9:95). The EIG spectrum

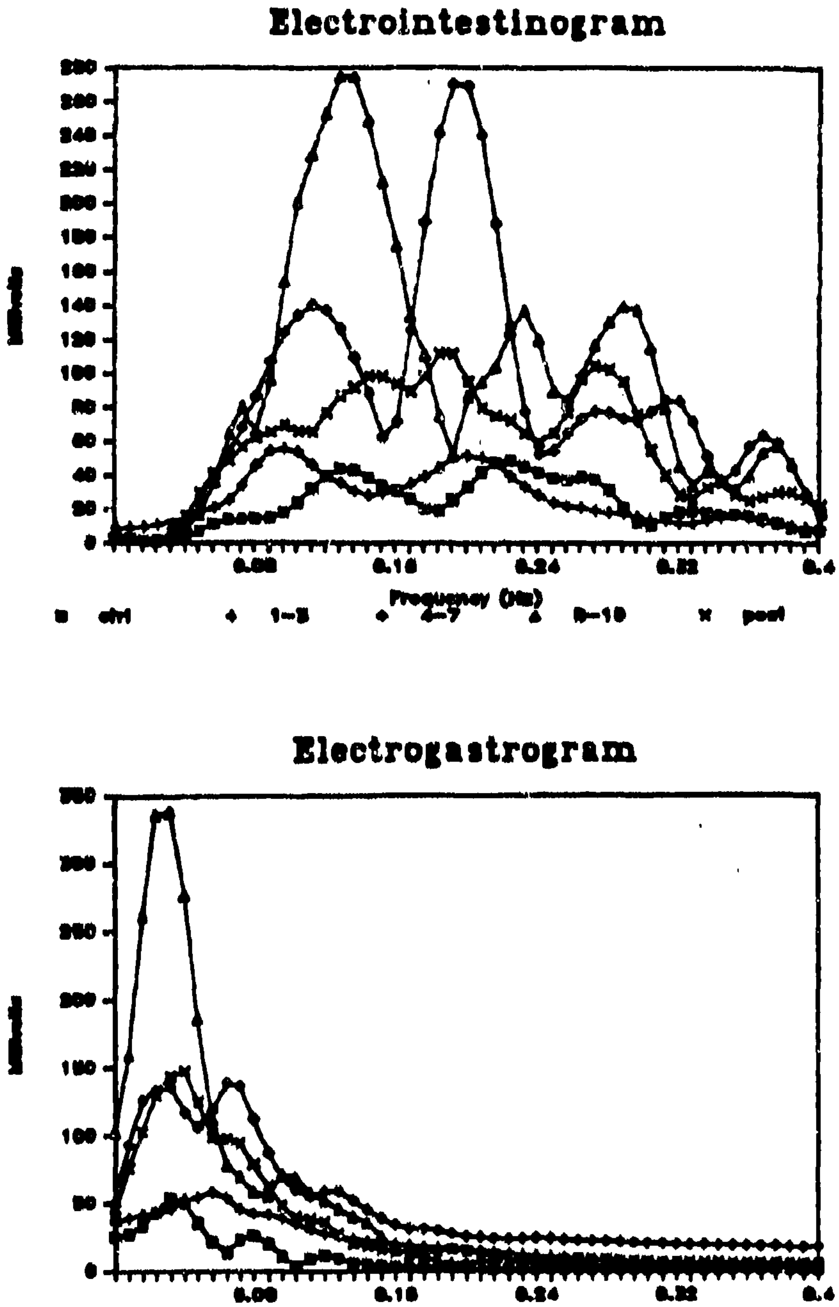
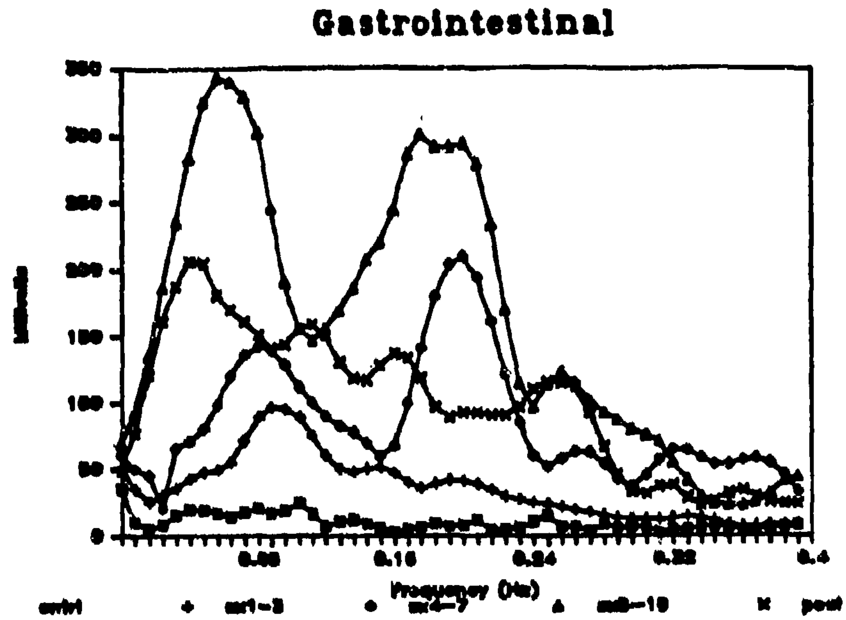


Figure 26 Spectrum of EIG and EGG



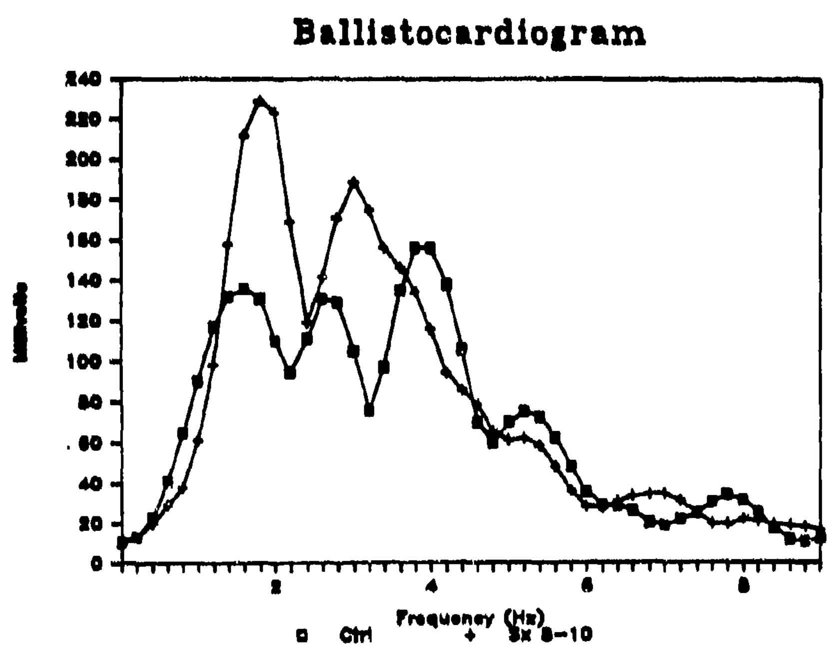
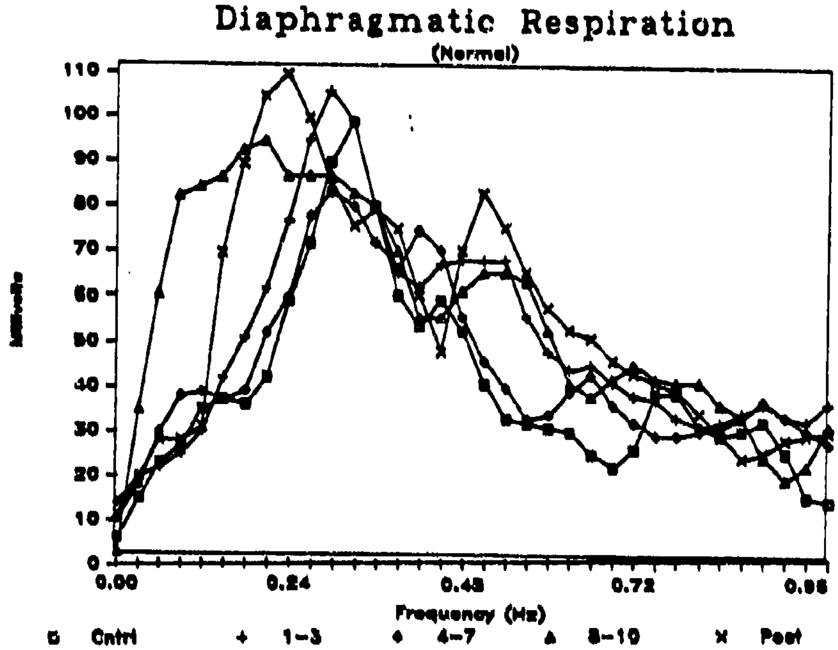


Figure 27 Spectrum of Gastrointestinal and Ballistocardiogram



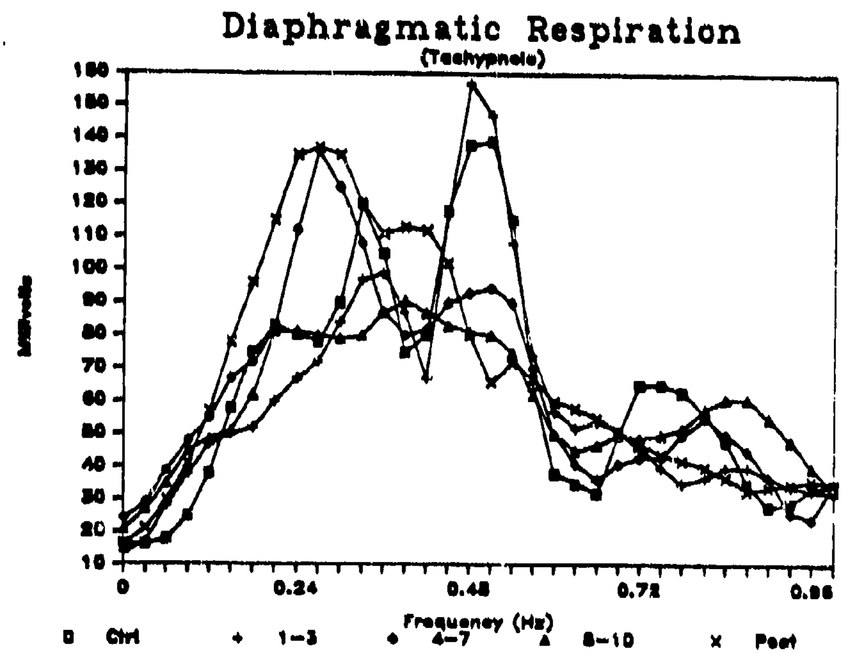
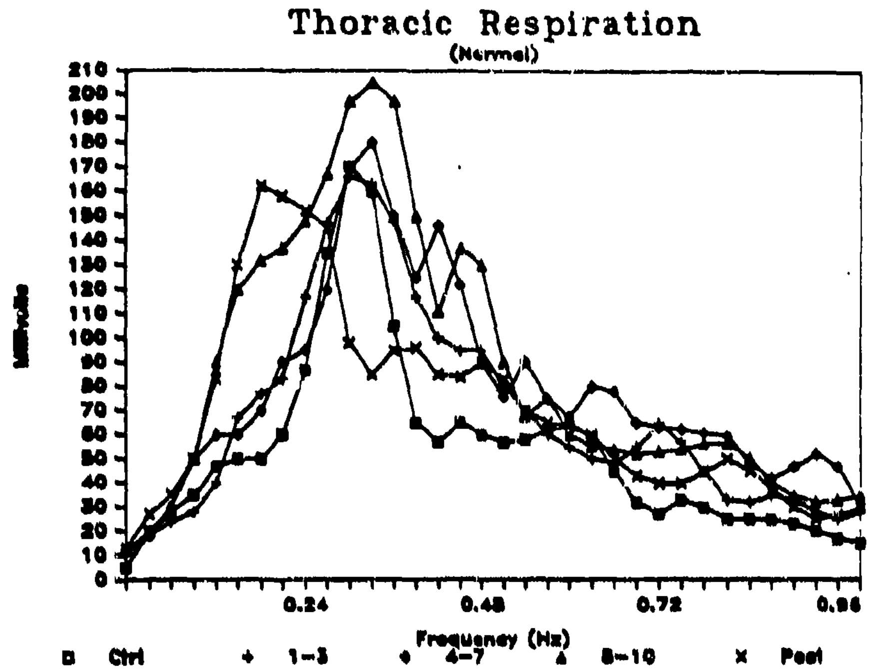


Figure 28 Spectrum of Diaphragmatic Respiration



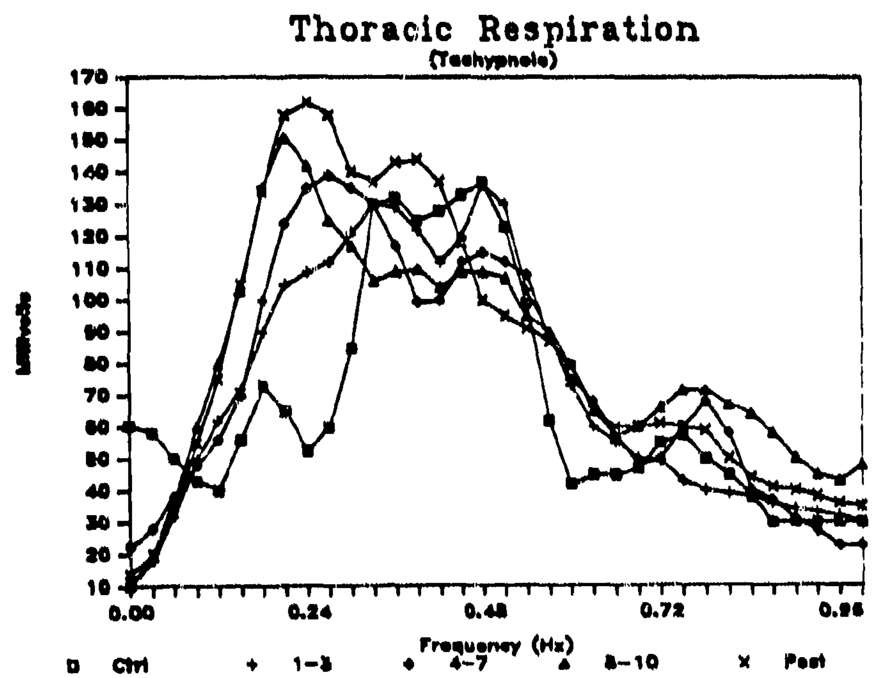
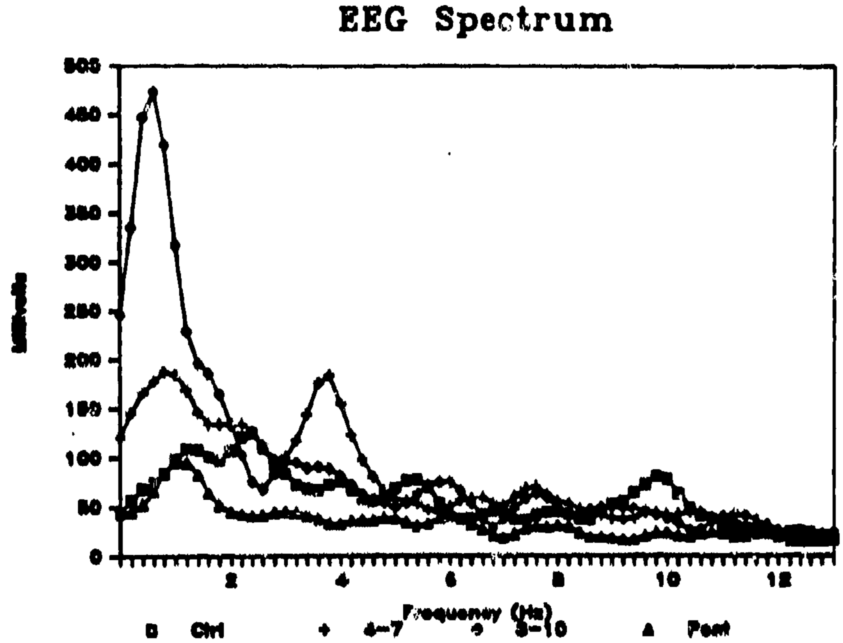


Figure 29 Spectrum of Thoracic Respiration



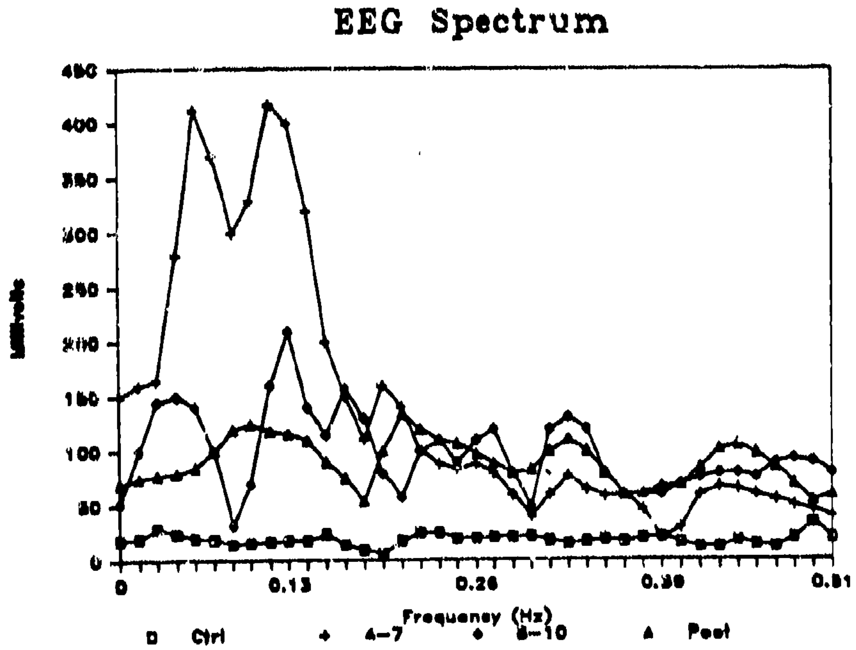


Figure 30 EEG Spectrum

indicates that amplitude increased from the control interval up through symptoms 4-7 interval. Even though the amplitude stayed about the same from symptoms 4-7 interval to symptoms 8-10 interval, a definite shift in frequency was observed. The majority of EIG activity appeared to occur at 0.20 Hz for symptoms 4-7 interval while it shifted to 0.12 Hz during symptoms 8-10 interval. This suggests that intestinal activity slowed down from BER of the control interval. However, the mean frequencies between intervals were not as varied. The control phase had a mean frequency of 0.21 Hz, symptoms 1-3 mean frequency was 0.20 Hz, symptoms 4-7 was 0.17 Hz, symptoms 8-10 was 0.19 Hz, and the post interval had a mean frequency of 0.20 Hz. Mean frequencies were calculated by summing the products of the amplitude and the frequency and then dividing that value by the sum of the amplitudes.

Electrogastrogram (EGG)

The EGG spectrum was useful as an amplitude measure as well as a display of mean frequency shifts. As can be seen in the graph, the amplitude levels increased with the onset of motion sickness. This indicates that gastric tone and motility increased with increasing motion sickness symptoms. There was a shift in mean frequecies between intervals. The control interval had a mean frequency of 0.07 Hz. This shifted to a mean frequency of 0.117 Hz during symptoms 1-3 interval and even higher to 0.121 Hz at symptoms 4-7. Upon reaching symptoms 8-10, the mean frequency again shifted to 0.062 Hz. The post interval

had a mean frequency of 0.089 Hz.

Respiration

While the descriptive statistical information on diaphragmatic respiration was uncertain due to assumed linear calibration with thoracic breathing, the spectral results were more conclusive. From the four spectra of respiration, it is evident (because of the increase in amplitude) that there was a significant recruitment in the subject's diaphram from the control phase until the onset of motion sickness. Frequency means for both classification of breathers were also calculated and are listed in the following table:

Table 5 Mean Frequencies for Respiration

	Phase	Hz
Diaphragmatic (normal)		
	Control	.64
	Sx 1-3	.71
	Sx 4-7	.71
	Sx 8-10	.64
	Post	.65
Diaphragmatic (tachypneic)		
	Control	.69
	Sx 1-3	.66
	Sx 4-7	.71
	Sx 8-10	.77
	Post	.64
Thoracic (normal)		
	Control	.60
	Sx 1-3	.64
	Sx 4-7	.64
	Sx 8-10	.62
	Post	.62
Thoracic (tachypneic)		
	Control	.60
	Sx 1-3	.62
	Sx 4-7	.59
	Sx 8-10	.71
	Post	.62

EEG Spectrum

The analysis of EEG was sampled both at the 25 Hz and the 1 Hz range. This was done mainly because the strip chart recordings showed the possibility of very low frequency brain wave activity occuring during the onset of motion sickness. EEG electrodes were placed on the subject's forehead.

The brain waves most commonly studied are alpha with a frequency of 8 to 13 Hz and are found in normal adults in a quiet, resting state (17). As indicated by the graph, it is apparent that there is indeed a significant amplitude of EEG at the 0.1 Hz frequency range. Also, there was a large frequency shift from .25 Hz to .16 Hz during the onset of motion sickness. This is perhaps the most significant finding of this thesis. However, it should be noted that the amplifiers used in transmitting this signal have a cutoff at 0.1 Hz of -3 db/octave. This means that at the 0.1 Hz range, only one-tenth of the actual signal is shown in the spectrum plot. Nevertheless, it appears that there is definitely a low frequency component of EEG during the onset of motion sickness. If this extremely low frequency component can be verified through more test runs, it would be of great interest since no where in the literature has such a low EEG frequency component been reported.

IV Model Implications

Introduction

Using the results from the descriptive statistical analysis, it is possible to construct an empirical predictive model for various stages of motion sickness. If a suitable relationship can be explained, then it can be used on additional test runs to verify its usefulness or aid in selecting a more appropriate experimental design. The most basic type of relationship to build and explain is a linear relationship. One method that allows building a linear predictive model is regression analysis.

Regression Theory

Regression analysis is a part of multivariate statistics that deals with investigating the relationship between two or more variables related in a nondeterministic fashion (7:423). It is a natural extension of the idea of simple linear regression to consider the regression of one variable on several independent variables. The need stems from the fact that the relation with any one independent variable (physiologic channel) does not give a high enough correlation to be of much value (24:23). Additional variables may contribute more.

Multiple regression can be used to predict a dependent variable based upon various predictor variables. It is necessary to have a relationship between motion sickness and the set of measurable physiologic channels. Motion sickness represents the dependent or predicted variable while the physiologic channels represent the independent or predictor variables. The

deterministic mathematical relationship between variables is a linear relationship :

$$Y = B_0 + B_1 x_1 + B_2 x_2 + \ldots + e$$

where B_1, B_2, etc are the coefficients of variables x_1, x_2 respectively, B_0 is the Y intercept, and e is the residual error. The parameters can therefore be estimated (7:427). The regression line provides a good fit to the data if the vertical distances (deviations) from the observed points to the regression line are small. The measure of goodness of fit is the sum of the squares of these deviations. The best-fit regression line is then the one having the smallest possible sum of squared deviations (7:427). The results from the correlation analysis will be used as a starting point for choosing which physiologic parameters will be the independent variables that can be regressed on the dependent variable called motion sickness.

Predictive Motion Sickness Model

A predictive model can be constructed by arranging the subject data into a multiple regression matrix. The rows of data in a regression matrix represent the variables, while the columns represent case values for each variable. To use matrix operations in regression, the number of variables must be less than the number of case values for each variable. Likewise, all variables must contain the same number of elements. This was the guiding force behind selecting the five symptomatic intervals.

Table 6 shows the mean values of each physiologic parameter that was selected as a result of the correlation analysis.

A multiple regression analysis was then performed using the software package Microstat. The primary predictor variables selected were Thoracic, Finger and GSR since they showed the highest correlation to motion sickness (each with a significance value higher than 95%). The parameters EKG, Temp and Breath were used in a secondary manner since they were only moderately correlated to motion sickness.

The overall prediction equation for motion sickness can be described linearly by the following:

$$\begin{aligned} Y = 0.9358 &+ 0.0095(\text{Thoracic}) + 0.1465(\text{Finger}) \\ &- 0.0004(\text{GSR}) + 0.0334(\text{EKG}) + 0.2449(\text{Temp}) \\ &+ 0.3696(\text{Breath}) \end{aligned}$$

In this equation the variable Y indicates the possible range of symptom numbers that are obtained from various instances of the given physiological parameters. The right side of the equation indicates that, if one is given the instantaneous values of each parameter, then the symptom level of motion sickness (over the range 1-10) can be predicted.

Once a prediction equation for motion sickness was found, an Analysis of Variance (ANOVA) table was constructed in order to test the significance of the regression (8:31). Table 7 shows the values used for this model.

Table 6 Mean Values for Individual Changes in Physiologic Parameters

Subj	Phase	Thoracic	Finger	GSR	EKG	Temp	Breath	Msick
1	Data is incomplete for GSR parameter							
2	Contr	0.00	0.00	0.00	0.00	0.00	0.00	1
	Sx1-3	100.00	1.70	233.60	9.80	0.05	1.26	2
	Sx4-7	303.30	2.30	614.90	2.60	0.10	2.73	6
	Sx8-10	445.80	0.45	605.20	5.50	9.40	3.08	9
3	Sx1-3	59.60	6.43	138.90	8.40	0.00	0.68	2
	Sx4-7	161.10	12.22	366.70	11.33	0.05	0.53	6
	Sx8-10	416.70	11.00	426.70	6.60	14.35	0.65	9
4	Sx1-3	93.80	14.38	235.90	17.50	0.78	0.59	2
	Sx4-7	89.30	11.07	426.70	16.10	0.40	0.55	6
	Sx8-10	675.00	3.75	426.70	14.50	5.30	0.78	9
5	Sx1-3	141.70	0.10	24.20	29.90	0.20	1.10	2
	Sx4-7	177.40	2.67	61.90	19.60	1.40	0.57	6
	Sx8-10	331.70	8.10	161.00	4.90	9.30	0.10	9
6	Sx1-3	111.30	7.38	13.10	1.50	0.15	0.36	2
	Sx4-7	408.30	5.20	28.30	3.50	1.00	1.58	6
	Sx8-10	456.30	5.83	53.70	1.20	2.00	1.31	9
7	Sx1-3	88.50	1.97	31.50	9.90	0.85	0.36	2
	Sx4-7	287.50	10.45	15.50	10.00	0.30	0.91	6
	Sx8-10	272.20	27.26	4.80	6.80	0.35	0.74	9
8	Sx1-3	82.40	17.63	176.50	26.60	0.10	1.07	2
	Sx4-7	25.00	20.55	300.00	26.50	0.10	2.00	6
	Sx8-10	266.70	14.97	257.30	10.50	8.15	2.42	9
9	Sx1-3	57.20	1.79	70.20	27.50	0.00	0.76	2
	Sx4-7	8.30	19.17	38.70	20.90	0.15	0.59	6
	Sx8-10	118.80	16.43	65.30	17.20	5.75	0.98	9
10	Sx1-3	144.60	1.76	257.30	3.20	0.15	0.40	2
	Sx4-7	333.40	13.33	195.90	2.50	0.65	0.24	6
	Sx8-10	375.00	23.75	229.20	1.50	15.00	0.65	9
11	Sx1-3	8.70	5.50	11.20	18.50	0.25	0.92	2
	Sx4-7	187.50	17.50	11.20	0.80	0.60	0.25	6
	Sx8-10	79.20	22.50	11.20	2.30	8.85	0.67	9
12	Sx1-3	139.60	0.76	86.90	11.50	0.15	0.83	2
	Sx4-7	154.10	2.50	153.00	30.50	0.35	0.34	6
	Sx8-10	176.60	7.00	236.60	30.20	9.00	0.49	9

Table 7 ANOVA for Regression Significance

Source	df	S.S.	M.S.S.	F
Reg S.S.	6	376.10918	62.68486	30.970
Res S.S.	37	74.89082	2.024076	
Tot S.S	43	451.00000		

The F value from the model is 30.970. This is compared to the F value calculated from the standard tables (7:624). Since the model F value is much greater than the tabulated F value (8.94), we conclude that the model is useful for predicting motion sickness symptom intervals.

Another indication of a good model fit is the R-squared value of the regression. In this case the R-squared value is 0.834 which means that 83.4% of the variation in the dependent variable can be explained or predicted through knowledge of the independent variables using a straight line equation.

Finally, the residuals from the regression equation indicate that a linear relationship provides a good fit. The residuals describe the difference between the observed values of Y and the predicted values of Y (7:434). Ideally, a perfect linear relationship would be one that had no residual error; however, this is not the case. Table 8 shows the residual errors for the regression.

Table 8 Residual Error Values for Regression Model

Observed Y (Motion Sick Interval)	Calculated Y	Residual
1.0	0.998	0.0025
2.0	2.005	-.0049
3.0	2.997	0.0031
4.0	3.999	0.0009
5.0	5.004	-.0042
6.0	6.009	-.0094
7.0	6.994	0.0065
8.0	7.982	0.0178
9.0	9.007	-.0069
10.0	10.005	-.0054

V Conclusions and Recommendations

Conclusions

The collection and statistical analysis of biophysical data on motion sick subjects proved to be an enormous task. Each test run lasted well over two hours and resulted in generating large amounts of data. At the time of this writing, the descriptive statistical analysis was performed manually by sampling the strip chart recordings since the Masscomp MC500 computer was inoperative. Spectral analysis could be performed after many weeks of editing subject data.

Overall, the system was very effective in both eliciting a motion sick response from the subject and in collecting and storing the biophysical data for later analysis. Changes to the hardware as well as quantifying more of the physiologic parameters through new calibration techniques, enabled a more accurate and complete statistical analysis of the data. Thoracic respiration, finger pallor, and galvanic skin reflex were shown to be highly predictive parameters of motion sickness. Heart rate, surface skin temperature, and breathing rate were not as strongly correlated with motion sickness but added to the overall effectiveness of constructing a predictive motion sickness equation.

A major finding during the spectral analysis was the discovery of a very low frequency brain wave occuring during the onset of motion sickness on the order of 0.1 Hz. However, it is necessary to add increased frequency response range to the EEG

preamplifiers to verify the actual low frequency component and also to collect more data to confirm these findings.

Multiple regression analysis was performed as a last step in this project to develop an initial predictive model for motion sickness. Only those parameters that could be used in a descriptive statistical manner were used because of the need for a practical model. Those parameters that required spectral analysis could not be included because a spectrum analyzer could not be incorporated in a real-time biofeedback system.

Applications to Further Research

This thesis has established a reliable biophysical data acquisition system and an accurate statistical analysis procedure. With only the data from 12 subjects to form a sample of a much larger population, it is necessary to continue to collect more data to confirm the results of this thesis. Also, it is a relatively easy task to incorporate the predictive model in an automated fashion to test and verify its accuracy. The model may then be used as a major element in building a biofeedback system to prevent motion sickness.

Recommendations

The Masscomp MC500 computer was under repair for the majority of this thesis; therefore, any potential future use is questionable. However, at the time of this writing, there exist Analog to Digital systems that support 16-channel data collection, are relatively inexpensive, and can be used at the

microcomputer level. Once room 150 is air-conditioned, the Masscomp MC500 may be colocated with the rest of the system and then its performance can be re-evaluated. The BDAS software was not tested again and still requires some minor debugging. Commercial software for data analysis is now available for the microcomputer A/D systems.

The strip chart recordings are the only hardcopy output of the entire experimental session. All relevant data should be marked on them as the experiment progresses. It is beneficial to record each tape recorder counter values at specific time periods as they occur. The most obvious and significant time periods are:

1) 60 seconds before chair rotation for baseline data
2) at the start of chair rotation
3) when head motions begin
4) at each symptom the subject reports
5) when head motion stops
6) when chair rotation stops
7) when test run stops

The strip chart recorders should be consistently marked for each experimental test run. Switching pens and recorder signal wires confused data reduction and often required playing back many channels to ensure the identity of each signal. Logistical considerations should be stressed before each test run. Batteries often ran low and the demand for electrodes, medical tape and strip chart recording paper always pressed the supply

capability.

The basic statistical procedure has been developed; however, more data must be collected to confirm these initial findings. The predictive equation for motion sickness should now be incorporated into the experimental test runs to test its validity. Even though a linear relationship has been formulated, non-linear techniques should also be explored to determine if a better fitting model is possible.

Finally, all parameters should be scrutinized to see if they are in phase, out of phase, or periods of both throughout a test run. This will confirm whether each variable is independent or shows correlation in another physiological manner. This procedure would be necessary to validate certain spectral analysis findings such as the discovery of a very low frequency EEG wave previously mentioned.

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Appendix A Motion Sickness Protocol

86-13--21 July 1986--Page 1

1. Title: Motion Sickness: A Study of its Etiology and A Statistical Analysis.

2. Principal Investigator: Dr. William Czelen, M.D.; 255-5276; AFIT/ENG.
   Associate Investigator: Dr. Matthew Kabrisky, Ph.D.; 255-5276; AFIT/ENG.
   Captain Michael McPherson; 255-5533; AFIT/ENG.
   Captain Dana Hartle; 255-5533; AFIT/ENG.
   Captain Robert Miller; 255-5533; AFIT/ENG.

3. Date: 21 July 1986   Type: Facility   Renewal: No

4. Synopsis

   The objective of this research is to investigate the causes of motion sickness and to develop a metric that can be used to determine each individual's susceptibility to motion sickness symptoms. The research will expand on the work done by previous researchers (Levy, Jones, & Carlson, 1981; Lackner & Graybiel, 1983; etc) by measuring more than one or two physiologic parameters at a time. This research will simultaneously measure 16 parameters utilizing a system developed by researchers at the Air Force Institute of Technology (Earl & Peterson, 1983; Fitzpatrick, Rogers, & Williams, 1984; Jarvis & Uyeda, 1985). By measuring this many physiologic variables at once, it is hoped that the extremely complex physiologic interrelationships involved in motion sickness symptomatology can be more easily studied and analyzed.

5. N/A.

6. Attachments: Consent Form
   Addendum to Consent Form
   Protocol Curricula Vitae

AFIT/EN Research Protocol

I. IDENTIFICATION

1. Title: Motion Sickness: A Study of its Etiology and A Statistical Analysis.
2. Date: 21 July 1986
3. Project/Task/Work Unit: N/A.
4. Principal Investigator: Dr. William Czelen, M.D.; 255-5276; AFIT/ENG.
5. Associate Investigator: Dr. Matthew Kabrisky, Ph.D.; 255-5276; AFIT/ENG.
   Captain Michael McPherson; 255-5533; AFIT/ENG.
   Captain Dana Hartle; 255-5533; AFIT/ENG.
   Captain Robert Miller;255-5533 AFIT/ENG.
6. Medical Consultant: Colonel Charles Hatsell; USAF/MC.

II. RESEARCH BASIS

1. Objective

   a. To investigate and quantify motion sickness symptoms in an attempt to predict the onset of motion sickness symptoms as well as develop a motion sickness metric to improve the ability of determining individual motion sickness susceptibility.

   b. To standardize the experimental procedures of every motion sickness experiment in order to facilitate statistical analyses.

   c. To initiate the incorporation of biofeedback techniques into motion sickness experiments.

2. Background and Relevance

The physiological characterization of motion sickness has spawned new research regarding possible predictive parameters. Previous efforts suggest that there are relationships between the onset of motion sickness symptomatology and specific measurable physiological criteria. Only a few physiological variables (i.e. skin conductance response and surface skin temperature) have been identified as predictive parameters of this vestibular maladaptation syndrome. Therefore, attempts to model motion sickness have met with little success.

We propose to accurately monitor at least 14 physiologic analog channels from a subject experiencing motion sickness symptoms. As recommended in the literature, the subject will encounter motion sickness symptoms by rotating about their vertical axis (planetary yaw) as they are seated in a rotating chair and tilting their head out of the axis of rotation. Physiologic sensors attached to the subject will transmit data to recording equipment via slip-rings on the rotating chair. This will allow us to collect sufficient data for valid statistical analysis and possibly lead to the development of a motion sickness model. Also, identifying those physiological parameters that are most closely associated with motion sickness may be useful in treatment by providing information for biofeedback techniques.

3. Impact

Additional testing is required to collect enough data for a valid statistical analysis. There is a definite need to study multiple channels simultaneously since prior relationships were developed between only one or two variables and did not give a high enough correlation to be of much value. Without this, the motion sickness syndrome and its possible trigger mechanism will remain unknown. Desired data cannot be derived from valid animal studies or from reliable computer modeling techniques.

4. Experimental Plan

a. Equipment and Facilities

(1). All experimental test sessions and data collection will be conducted in the AFIT Engineering Building 640, room 150.

(2). All experiments will consist of a test subject performing head movements in a rotating chair. The required head movements are broadcast on a self-contained, hand held cassette tape recorder and instruct the subject to make a head movement every 10 seconds.

(3). Overall, the following equipment will be used:

(a). equipment-subject interface:

1. Rotating chair for eliciting the motion sickness response.
2. Chair control console which controls the chair's rotation speed.
3. NDM Corporation Silvon Stress Test ECG electrodes and Medtronic Medical "Huggables" Infant Monitoring Electrodes (Note: All electrodes and sensors connect through high resistance (100K to 1Mega ohm) isolation resistors connecting to battery-powered (12 Volt Lantern Batteries) amplifiers and processing circuitry. The data passes through slip-rings to data recording equipment.
4. Safety belt to hold the subject in the rotating chair (this is an added safety precaution).
5. Self-contained battery, hand-held, portable tape recorder used for letting the test subject know what head movement to make.
6. An Astropulse 90 Blood Pressure Cuff to record blood pressure.
7. Manual blood pressure cuff for pallor calibration.
8. Two pneumographs used to measure respiration (both abdominal and thoracic). The pneumographs are circumferential belts that employ strain guages to detect respiration rate and depth changes (Note: The pneumographs are electrically isolated from the subject).
9. Two thermistors for measuring skin temperature
   a. One thermistor is connected to an AUTOGEN 1000 Temperature Indicator
   b. The other thermistor is attached to the fourth digit of the test subject.
9. Two Galvanic Skin Response (GSR) electrodes for measuring skin conductance.
10. Two plethysmographs for measuring blood flow volume (pallor).
    a. the plethysmographs are LED and photo transistors and one is attached to the third digit and the other is attached to the test

subject's forehead. Both plethysmographs are self-adhesive and in a balsa housing.

(b). offline equipment:

1. Three Brushmark 260 6 channel strip-chart recorders.
2. A Hewlett-Packard 3582A Spectrum Analyzer will be used for signal averaging.
3. A VAX 11/785 computer or a Zenith 241 computer will be used for statistical data analysis.
4. A Kyowa Dengyo RTP-610A Data Recorder.
5. An AMPEX FR 1300 14 track FM recorder

b. Method

As much as possible, each experiment will be standardized and follow an identical approach. The first step of the experiment will entail the human volunteer filling out a Medical History Questionnaire, an AFIT Motion Sickness Questionnaire, and a Subject Consent Form. Additionally, each test candidate will receive both a written and an oral briefing describing what he/she can expect to experience during the experiment, as well as have any questions answered by the experimenters.

The second step of the experiment will consist of a medical examination (See Attachment 4) by the attending physician, Dr. William Czelen, to determine each subject's physical capability to participate in the experiment. Once the subject's exam is completed and no problems cited, the subject will have electrodes of the silver/silver chloride type attached. Parameters to be studied will be electrocardiogram, electroencephalogram, nystagmus, galvanic skin response, pulse rate, blood pressure, electrointestinograph (a surface electrode over the abdomin for measuring surface potential. This procedure is similar to that of the elctrocardiogram), temperature, electrogastrogram (the same procedure as the electrointestinograph), respiration, and pallor. Prior to each electrodes placement, the site will be thoroughly and vigorously scrubbed

with alcohol pads in an attempt to remove the outermost layer of epidermis and oil to assure good electrical contact. Once all electrodes are in place and the electrode leads attached to the appropriate electrode, the subject will be assisted into the chair and then restrained by safety belts. The subject's eyes will then be covered by ocular patches and a blindfold to prevent any extraneous visual stimuli. Also the subject will receive final instructions on the tape recorder's operation. The tape recorder is used to give instructions to the test subject regarding the appropriate head movements during the experiment.

The third step in the experiment will consist of spinning the subject in addition to the subject performing the necessary head movements to elicit a motion sickness response. The chair will initially spin at a rate of 14 revolutions per minute. The subject's vital signs will be allowed to stabilize for approximately two minutes during which time the subject will not perform any head movements. Approximately five seconds after the subject is instructed to start the tape recorder, the individual will commence random left, right, forward, and upward head movements at ten second intervals. The subject's physiological state will be constantly monitored and the subject will be asked for verbal inputs on his/her condition. If after two minutes, the subject shows no signs of motion sickness, the chair speed will be increased by two RPMs. Thereafter, every two minutes the chair will be increased by two RPMs if the subject shows no motion sickness signs. Maximum speed of the chair is 30 RPMs and if a test subject rides the chair long enough to get to the 30 RPM state, then the test subject will ride at this speed until a motion sickness response is elicited.

Upon the subject's request to stop the experiment, the chair will be decelerated at a rate of approximately five revolutions per minute to avoid any further provocative stimulus. After the chair has come to a complete stop, the subject will remain seated until all physiological indicators return to a state that approaches the pre-test values. All power to the chair control console will then be removed to prevent accidental chair acceleration. After the subject stabilizes, the

blindfold and ocular patches will be removed and the subject assisted from the chair. All electrode leads and electrodes are next removed. After a post experiment interview with the subject regarding his/her comments about the experiment and with the approval of the physician, the subject will then be released.

c. Subjects

Subjects will be chosen at random using personal contact and publicity. Both DOD military and civilian volunteers will be chosen. We hope to attract a wide spectrum of test subjects, to include healthy, adult males and females with no chronic, disabling injuries. Additionally, no special training is required. Each potential test subject will fill out a Medical History Questionnaire and receive a relevant medical evaluation to determine their fitness for participating in the experiment. Subjects will participate in only one experiment and each experiment's length will depend on an individual's susceptibility to motion sickness but will not exceed an hour. The total number of subjects run will depend on the number of volunteers we receive

d. Reporting

All test data will not be associated with the subject's name. Any publication of the data will not reveal an individual's name or any other subject specific information. Data will not be available to anyone other than the investigators. Upon request, subjects will be debriefed on the general results of the study. However, after each experimental test session, the test subject will be shown the results of their particular test session.

e. Schedule

The time frame for the experiments will begin upon protocol approval and it is anticipated all data should be collected by July 1987.

f. Data Analysis

The data will be subjected to a variety of statistical analyses. The major analysis

techniques will be analysis of variance (ANOVA) and time series analysis.

III. Medical Risks, Safety Precautions, and Measures

This research using human subjects places the subjects at minimal risk in accordance with the definition of risk in AFR 169-3.

Standard medical history and physical evaluations (See Attachment 4) are administered prior to each experiment.

No history of subject harm has been reported in previous studies. As part of the initial informed consent briefing subjects will be assured that if discomfort or displeasure is experienced, they are free to terminate the exposure without prejudice.

All physiologic sensors and instrumentation are battery powered (12 volts). All electrodes with direct electrical contact with the subject are isolated from the onboard signal processing instrumentation and power supplies through 100,000 to 1 million ohm resistors.

The modified MATS chair has been man rated and used safel over the years in several prior experiments. Further, only the planetary component of rotation is used and only in the yaw axis, eliminating risk from cab tilting or rolling. As an added safety precaution, the subject is secured in the cab by a seat belt.

Finally, as part of the calibration procedures before an experiment, the subject's forearm and hand are tightly wrapped for approximately a minute with an elastic bandage to blanch the region--a period too short to create any clotting danger or discomfort.

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PROTOCOL CURRICULUM VITAE

1. Name: William E. Czelen, M.D.
   Grade or Rank: N/A (On a grant)

2. Current Position Title: Senior Research Associate.
   Location: AFAMRL/AFIT, Wright-Patterson AFB, Ohio.

3. Education:
   B.S., Electrical Engineering, Carnegie-Mellon University, Pittsburg, Pa. 1971.
   B.S., Biology, University of Pittsburg, Pittsburg, Pa. 1973.
   M.D., Temple University School of Medicine, Philadelphia, Pa. 1979.
   M.S., Wright State University School of Medicine, Dayton, Ohio, 1986

4. Relevant Experience:
   1985-1986: Senior Research Associate-National Research Council/Air Force School of Aerospace Medicine AFAMRL/AFIT.
   1986 : Clinical Instructor-Wright State University Department of Community Medicine.
   1983-1985: Residency in Aerospace Medicine-Wright State University Department of Community Medicine.
   1984-1985: Physician-Wright State University/FAWCAC.
   1983-1985: Emergency Room Physician-Independent contractor in Western Ohio.
   1982-1983: General Medical Practice-Washington, D.C.
   1982-1983- Medical Director, Consumer Medical Services-Manna Corp, Arlington, VA.
   1979-1981: Residency in Anesthesiology/Critical Care Medicine-Georgetown University Hospital, Washington, D.C.
   1979 : National Aeronautics and Space Administration/Johnson Space Center, Houston, TX.
   1973 : Endocrinologic Research Assistant-University of Pittsburg School of Medicine, Pittsburg, PA.
   1968 : WTAE Radio/Hearst Corp-Radio Engineer-Wilkensburg PA.

5. Licensure:
   1983: Doctor of Medicine-Ohio State Medical Board.

   1980: Medicine and Surgery-District of Columbia.

   1980: Diplomate-National Board of Medical Examiners.

   1967: 1st Class Commercial Radiotelephone.

   1964: Advanced Class Amateur Radio.

Current as of July 1986.

PROTOCOL CURRICULUM VITAE

1. Name: Matthew Kabrisky, Ph. D.
   Grade or Rank: GM-15.

2. Current Position Title: Professor of Electrical Engineering.
   Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:
   B.S., Electrical Engineering, Polytechnic Institute of Brooklyn, 1951.
   M.S., Electrical Engineering, Polytechnic Institute of Brooklyn, 1952.
   Ph.D., Electrical Engineering, University of Illinois, 1964.

4. Relevant Experience:

   Member of the Series of Biomedical Engineering Research Team with AMRL since 1964.

5. Licensure: N/A.

Current as of 23 July 1986.

PROTOCOL CURRICULUM VITAE

1. Name: Robert Miller
   Rank: Captain, USAF.

2. Current Position: Student at the Air Force Institute of Technology; Graduate in Computer Systems.
   Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:
   B.S.; Business Administration, Pennsylvania State University 1976.
   M.S., Computer Systems, Air Force Institute of Technology, (May 1985 - Present).

4. Relevant Experience:

   Based on courses taken at AFIT since enrollment in 1985.

5. Licensure: N/A.

Current as of 24 July 1986.

PROTOCOL CURRICULUM VITAE

1. Name: Michael R. McPherson
   Rank: Captain, USAF.

2. Current Position: Student at the Air Force Institute of Technology, Graduate in Computer Systems.
   Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:
   B.S., Biology, USAF Academy, 1981.
   M.S., Systems Management, Western New England College, 1985.
   M.S., Computer Systems, Air Force Institute of Technology, (May 1985 -Present).

4. Relevant Experience:

   Undergraduate Pilot Training - Sept 1981-April 1982.

5. Licensure: N/A.

Current as of 24 July 1986.

PROTOCOL CURRICULUM VITAE

1. Name: Dana R. Hartle.
   Rank: Captain, USAF.

2. Current Position: Student at the Air Force Institute of Technology; Graduate in Computer Systems.
   Location: Air Force Institute of Technology, WPAFB, Ohio.

3. Education:
   B.S., Computer Science, Montana State University, 1982.
   M.A., Computer Data Management, Webster University, 1984.
   M.S., Computer Systems, Air Force Institute of Technology, (May 1985 - Present).

4. Relevant Experience:

   Based on courses taken at AFIT since enrollment in 1985.

5. Licensure: N/A.

Current as of 24 July 1986.

APPENDIX B - Subject Data

Parameter: Finger Photoplethysmograph   Date: 23 Jul 86
Subject: #1   Time: 1100 - 1115

Event	Time (sec)	Value (%)	Symptom
baseline	-	75	
	-	80	
	-	75	
	-	75	
	-	80	
start spin	0	80	1
	10	90	
	20	95	
	30	90	
	40	90	
	50	80	
	60	85	
head motion	70	90	
	80	90	
	90	85	
	100	85	
	110	80	
	120	80	
	130	75	
	140	70	
	150	75	
	160	75	
	170	75	
	180	75	
	190	80	4
	200	80	
	210	75	
	220	70	7
	230	70	
	240	80	9
	250	75	
	260	75	
	270	70	
	280	65	
stop head motion	290	60	
	300	70	
	310	70	
	320	65	
	330	70	
	340	70	
	350	65	
	360	60	
	370	65	
	380	65	
	390	65	
	400	65	
	410	65	

Parameter: Facial Photoplethysmograph
Subject: #1

Date: 23 Jul 86
Time: 1100 - 1115

Event	Time (sec)	Value (%)	Symptom
baseline	-	75	
	-	75	
	-	75	
	-	75	
	-	75	
start spin	0	80	1
	10	80	
	20	80	
	30	75	
	40	75	
	50	75	
	60	75	
head motion	70	75	
	80	75	
	90	75	
	100	85	
	110	80	
	120	80	
	130	85	
	140	85	
	150	85	
	160	90	
	170	90	
	180	90	
	190	90	4
	200	90	
	210	85	
	220	85	7
	230	100	
	240	105	9
	250	105	
	260	105	
	270	105	
	280	105	
stop head motion	290	105	
	300	105	
	310	105	
	320	105	
	330	105	
	340	105	
	350	105	
	360	105	
	370	105	
	380	105	
	390	105	
	400	105	
	410	105	

Parameter: Surface Skin Temperature Date: 23 Jul 86
Subject: #1 Time: 1100 - 1115

Event	Time (sec)	Value (F)	Symptom
baseline	-	92.1	
	-	92.1	
	-	92.1	
	-	92.1	
	-	92.1	
start spin	0	92.2	1
	10	92.3	
	20	92.3	
	30	92.3	
	40	92.4	
	50	92.4	
	60	92.4	
head motion	70	92.4	
	80	92.4	
	90	92.4	
	100	92.4	
	110	92.4	
	120	92.4	
	130	92.4	
	140	92.4	
	150	92.4	
	160	92.4	
	170	92.3	
	180	92.3	
	190	92.3	4
	200	92.3	
	210	92.3	
	220	92.3	7
	230	92.2	
	240	92.2	9
	250	92.2	
	260	92.1	
	270	92.1	
	280	92.1	
stop head motion	290	92.2	
	300	92.4	
	310	92.6	
	320	92.8	
	330	93	
	340	93.2	
	350	93.4	
	360	93.6	
	370	93.7	
	380	95	
	390	97	
	400	99.2	
	410	99.4	

Parameter: Electrocardiogram (EKG)
Subject: #1

Date: 23 Jul 86
Time: 1100 - 1115

Event	Time (sec)	Value(Beats/min)	Symptom
baseline	-	78	
	-	78	
	-	60	
	-	54	
	-	60	
start spin	0	66	1
	10	66	
	20	60	
	30	72	
	40	66	
	50	66	
	60	66	
head motion	70	60	
	80	72	
	90	78	
	100	72	
	110	78	
	120	72	
	130	72	
	140	75	
	150	81	
	160	75	
	170	78	
	180	84	
	190	90	4
	200	90	
	210	78	
	220	78	7
	230	84	
	240	84	9
	250	75	
	260	84	
	270	75	
	280	72	
stop head motion	290	75	
	300	96	
	310	78	
	320	72	
	330	69	
	340	69	
	350	72	
	360	72	
	370	72	
	380	66	
	390	63	
	400	72	
	410	72	

Parameter: Thoracic Respiration
Subject: #1

Date: 23 Jul 86
Time: 1100 - 1115

Event	Time (sec)	Value(Vol/#Breath)	Symptom
baseline	-	400/3	
	-	400/3	
	-	400/2	
	-	400/3	
	-	400/3	
start spin	0	400/1	1
	10	350/3	
	20	400/4	
	30	300/3	
	40	300/4	
	50	350/3	
	60	500/4	
head motions	70	450/3	
	80	450/3	
	90	550/4	
	100	650/3	
	110	600/3	
	120	600/2	
	130	650/2	
	140	700/2	
	150	750/3	
	160	800/3	
	170	850/2	
	180	900/2	
	190	800/3	4
	200	850/2	
	210	900/2	
	220	950/2	7
	230	950/1	
	240	1000/2	9
	250	1200/2	
	260	1200/2	
	270	1400/2	
	280	1100/1	
stop head motion	290	1100/2	
	300	1000/2	
	310	1100/3	
	320	1000/2	
	330	900/3	
	340	900/2	
	350	900/2	
	360	900/2	
	370	800/1	
	380	800/1	
	390	700/2	
	400	700/1	
	410	800/2	

Parameter: Diaphragmatic Respiration | Date: 23 Jul 86
Subject: #1 | Time: 1100 - 1115

Event	Time (sec)	Value(Vol/#Breath)	Symptom
baseline	-	100/3	
	-	100/3	
	-	100/2	
	-	100/3	
	-	100/3	
start spin	0	250/1	1
	10	250/3	
	20	300/4	
	30	250/3	
	40	250/4	
	50	400/3	
	60	300/4	
head motions	70	300/3	
	80	250/3	
	90	300/4	
	100	550/3	
	110	600/3	
	120	600/2	
	130	550/2	
	140	500/2	
	150	500/3	
	160	600/3	
	170	600/2	
	180	600/2	
	190	550/3	4
	200	450/2	
	210	450/2	
	220	400/2	7
	230	600/1	
	240	550/2	9
	250	550/2	
	260	500/2	
	270	550/2	
	280	600/1	
stop head motion	290	550/2	
	300	500/2	
	310	450/3	
	320	400/2	
	330	400/3	
	340	400/2	
	350	400/2	
	360	300/2	
	370	300/1	
	380	300/1	
	390	300/2	
	400	300/1	
	410	300/2	

Parameter: Finger Photoplethysmograph Date: 25 Jul 86
Subject: #2 Time: 1030 - 1033

Event	Time (sec)	Value (%)	Symptom
baseline	-	90	
	-	85	
	-	90	
	-	90	
	-	85	
start spin	0	90	1
	10	95	
	20	90	
	30	95	
	40	90	
	50	85	
	60	90	
head motions	70	95	
	80	90	
	90	90	
	100	85	
	110	85	2
	120	90	
	130	95	3
	140	85	
	150	85	4
	160	85	
	170	90	
	180	85	6
	190	85	7
	200	90	
	210	90	8
	220	95	
	230	95	
	240	85	
	250	85	9
	260	85	
stop head motion	270	85	
	280	80	
	290	80	
	300	75	
	310	75	
	320	75	
	330	75	
	340	75	
	350	70	
	360	70	
	370	75	
	380	75	
	390	75	
	400	70	
	410	75	

Parameter: Skin Surface Temperature
Subject: #2

Date: 25 Jul 86
Time: 1030 - 1033

Event	Time (sec)	Value (F)	Symptom
baseline	-	97.6	
	-	97.6	
	-	97.6	
	-	97.6	
	-	97.6	
start spin	0	97.6	1
	10	97.6	
	20	97.6	
	30	97.6	
	40	97.6	
	50	97.6	
	60	97.6	
head motions	70	97.6	
	80	97.6	
	90	97.6	
	100	97.6	
	110	97.7	2
	120	97.7	
	130	97.7	3
	140	97.7	
	150	97.7	4
	160	97.7	
	170	97.7	
	180	97.7	6
	190	97.7	7
	200	97.7	
	210	97.7	8
	220	97.7	
	230	97.7	
	240	97.8	9
	250	97.8	
	260	97.8	
stop head motion	270	97.8	
	280	97.8	
	290	97.8	
	300	97.7	
	310	97.7	
	320	97.7	
	330	97.7	
	340	97.7	
	350	97.6	
	360	97.6	
	370	97.6	
	380	97.6	
	390	97.5	
	400	97.5	
	410	97.5	

Parameter: Electrocardiogram (EKG)
Subject: #2

Date: 25 Jul 86
Time: 1030 - 1033

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	90	
	-	96	
	-	84	
	-	78	
	-	84	
start spin	0	66	1
	10	66	
	20	66	
	30	72	
	40	66	
	50	66	
	60	72	
head motions	70	78	
	80	78	
	90	78	
	100	78	
	110	78	2
	120	78	
	130	78	3
	140	78	
	150	78	4
	160	78	
	170	84	
	180	78	6
	190	84	7
	200	84	
	210	90	8
	220	90	
	230	90	
	240	90	9
	250	90	
	260	84	
stop head motion	270	90	
	280	81	
	290	81	
	300	93	
	310	84	
	320	78	
	330	84	
	340	84	
	350	72	
	360	72	
	370	84	
	380	84	
	390	72	
	400	75	
	410	75	

Parameter: Thoracic Respiration
Subject: #2

Date: 25 Jul 86
Time: 1030 - 1033

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	500/3	
	-	400/2	
	-	300/2	
	-	400/3	
	-	400/3	
start spin	0	500/3	1
	10	450/3	
	20	350/4	
	30	350/3	
	40	300/3	
	50	400/4	
	60	400/4	
head motions	70	450/3	
	80	400/4	
	90	450/4	
	100	650/4	
	110	650/5	2
	120	800/4	
	130	1000/6	3
	140	600/5	
	150	650/5	4
	160	750/6	
	170	550/6	
	180	850/5	6
	190	800/5	7
	200	750/6	
	210	850/5	8
	220	850/5	
	230	900/6	
	240	950/6	
	250	850/6	9
	260	850/6	
stop head motion	270	900/6	
	280	800/4	
	290	900/4	
	300	800/4	
	310	800/3	
	320	800/3	
	330	900/3	
	340	700/3	
	350	600/4	
	360	600/2	
	370	500/3	
	380	400/2	
	390	600/3	
	400	500/1	
	410	400/2	

Parameter: Diaphragmatic Respiration
Subject: #2

Date: 25 Jul 86
Time: 1030 - 1033

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	800/3	
	-	700/2	
	-	600/2	
	-	600/3	
	-	600/3	
start spin	0	700/3	1
	10	900/3	
	20	750/4	
	30	600/3	
	40	700/3	
	50	900/4	
	60	900/4	
head motions	70	950/3	
	80	750/4	
	90	900/4	
	100	800/4	
	110	800/5	2
	120	800/4	
	130	950/6	3
	140	750/5	
	150	700/5	4
	160	650/6	
	170	500/6	
	180	500/5	6
	190	500/5	7
	200	400/6	
	210	500/5	8
	220	500/5	
	230	600/6	
	240	600/6	
	250	550/6	9
	260	450/6	
stop head motion	270	400/6	
	280	500/4	
	290	500/4	
	300	500/4	
	310	600/3	
	320	600/3	
	330	500/3	
	340	400/3	
	350	500/4	
	360	600/4	
	370	500/2	
	380	500/3	
	390	400/2	
	400	400/3	
	410	400/1	

Parameter: Galvanic Skin Reflex (GSR) Date: 25 Jul 86
Subject: #2 Time: 1030 - 1033

Event	Time (sec)	Value (K)	Symptom
baseline	-	1000	
	-	975	
	-	950	
	-	925	
	-	900	
start spin	0	884	. 1
	10	875	
	20	875	
	30	875	
	40	875	
	50	875	
	60	865	
head motions	70	854	
	80	700	
	90	700	
	100	563	
	110	420	2
	120	420	
	130	420	3
	140	380	
	150	380	4
	160	340	
	170	380	
	180	350	6
	190	170	7
	200	280	
	210	180	8
	220	280	
	230	320	
	240	350	
	250	400	9
	260	420	
stop head motion	270	440	
	280	450	
	290	465	
	300	480	
	310	500	
	320	520	
	330	540	
	340	563	
	350	570	
	360	580	
	370	595	
	380	610	
	390	625	
	400	640	
	410	655	

Parameter: Finger Photoplethysmograph
Subject: #3

Date: 30 Jul 86
Time: 1018 - 1024

Event	Time (sec)	Value (%)	Symptom
baseline	-	90	
	-	90	
	-	90	
	-	90	
	-	90	
start spin	0	90	1
	10	90	
	20	90	
	30	90	
	40	95	
	50	80	
head motions	60	80	
	70	80	
	80	80	
	90	80	
	100	80	
	110	80	
	120	80	2
	130	75	
	140	75	
	150	75	5
	160	85	
	170	75	
	180	80	
	190	75	
	200	80	
	210	75	
	220	80	
	230	70	
	240	75	8
	250	85	
	260	85	9-10
stop head motion	270	80	
	280	75	
	290	75	
	300	70	
	310	65	
	320	65	
	330	70	
	340	70	
	350	70	
	360	70	
	370	75	
	380	70	

Parameter: Surface Skin Temperature
Subject: #3

Date: 30 Jul 86
Time: 1018 - 1024

Event	Time (sec)	Value (F)	Symptom
baseline	-	79.8	
	-	79.8	
	-	79.8	
	-	79.8	
	-	79.8	
start spin	0	79.8	1
	10	79.8	
	20	79.8	
	30	79.8	
	40	79.8	
	50	79.8	
head motions	60	79.8	
	70	79.8	
	80	79.8	
	90	79.8	
	100	79.8	
	110	79.8	
	120	79.8	2
	130	79.8	
	140	79.8	
	150	79.8	5
	160	79.8	
	170	79.8	
	180	79.9	
	180	79.9	
	190	79.9	
	200	79.9	
	210	79.9	
	220	79.9	
	230	79.9	
	240	80.0	8
	250	80.0	
	260	80.0	9-10
stop head motion	270	80.0	
	280	80.0	
	290	80.0	
	300	80.0	
	310	80.0	
	320	80.1	
	330	80.1	
	340	80.2	
	350	80.3	
	360	80.4	
	370	80.4	
	380	80.5	

Parameter: Electrocardiogram (EKG) Date: 30 Jul 86
Subject: #3 Time: 1018 - 1024

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	84	
	-	72	
	-	66	
	-	66	
	-	60	
start spin	0	66	1
	10	69	
	20	69	
	30	75	
	40	78	
	50	75	
head motions	60	81	
	70	84	
	80	84	
	90	84	
	100	78	
	110	78	
	120	90	2
	130	72	
	140	90	
	150	87	
	160	87	
	170	78	5
	180	90	
	190	75	
	200	75	
	210	66	
	220	75	
	230	69	8
	240	84	
	250	75	
	260	75	9-10
stop head motion	270	75	
	280	60	
	290	66	
	300	60	
	310	66	
	320	54	
	330	54	
	340	54	
	350	63	
	360	57	
	370	66	
	380	60	

Parameter: Thoracic Respiration
Subject: #3

Date: 30 Jul 86
Time: 1018 - 1024

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	700/3	
	-	650/3	
	-	600/3	
	-	600/2	
	-	600/2	
start spin	0	650/3.5	1
	10	650/3	
	20	700/2.5	
	30	800/2.5	
	40	700/3	
	50	700/3.5	
head motions	60	750/3	
	70	900/3.5	
	80	650/3.5	
	90	750/3.5	
	100	350/5	
	110	500/4	
	120	700/4	2
	130	900/3.5	
	140	700/3.5	
	150	900/2.5	5
	160	850/3.5	
	170	850/4.5	
	180	650/3	
	190	700/3	
	200	400/3.5	
	210	850/3	
	220	1250/3	
	230	1250/4	8
	240	1200/3.5	
	250	1000/3.5	
	260	900/3	9-10
stop head motion	270	900/3	
	280	900/3	
	290	1000/3	
	300	1200/3	
	310	1000/3	
	320	1000/2	
	330	900/3	
	340	900/2	
	350	1000/2	
	360	1000/2	
	370	800/2	
	380	1000/1	

Parameter: Diaphragmatic Respiration Date: 30 Jul 86
Subject: #3 Time: 1018 - 1024

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	350/3	
	-	300/3	
	-	300/3	
	-	300/2	
	-	300/2	
start spin	0	300/3.5	1
	10	300/3	
	20	300/2.5	
	30	400/2.5	
	40	400/3	
	50	500/3.5	
head motions	60	700/3	
	70	550/3.5	
	80	800/3.5	
	90	550/3.5	
	100	700/5	
	110	750/4	
	120	700/4	2
	130	750/3.5	
	140	700/3.5	
	150	550/2.5	5
	160	550/3.5	
	170	700/4.5	
	180	800/3	
	190	600/3	
	200	800/3.5	
	210	800/3	
	220	600/3	
	230	850/4	
	240	650/3.5	8
	250	400/3.5	
	260	400/3	9-10
stop head motion	270	400/3	
	280	500/3	
	290	600/3	
	300	500/3	
	310	450/3	
	320	400/2	
	330	450/3	
	340	500/2	
	350	500/2	
	360	500/2	
	370	500/2	
	380	500/1	

Parameter: Galvanic Skin Reflex (GSR) Date: 30 Jul 86
Subject: #3 Time: 1018 - 1024

Event	Time (sec)	Value (K)	Symptom
baseline	-	380	
	-	380	
	-	380	
	-	390	
	-	390	
start spin	0	390	1
	10	390	
	20	390	
	30	420	
	40	435	
	50	450	
head motions	60	465	
	70	495	
	80	540	
	90	570	
	100	585	
	110	690	
	120	765	2
	130	750	
	140	750	
	150	840	5
	160	780	
	170	810	
	180	780	
	190	735	
	200	660	
	210	690	
	220	720	
	230	870	
	240	750	8
	250	780	
	260	750	9-10
stop head motion	270	750	
	280	740	
	290	730	
	300	720	
	310	720	
	320	720	
	330	720	
	340	720	
	350	720	
	360	750	
	370	750	
	380	750	

Parameter: Finger Photoplethysmograph
Subject: #4

Date: 5 Aug 86
Time: 1054 - 1059

Event	Time (sec)	Value (%)	Symptom
baseline	-	50	
	-	75	
	-	80	
	-	75	
	-	80	
start spin	0	90	1
	10	90	
	20	90	
	30	90	2
	40	90	
	50	90	
head motion	60	85	
	70	90	3
	80	85	5
	90	90	
	100	90	
	110	90	
	120	85	
	130	85	
	140	85	
	150	85	
	160	85	6
	170	85	
	180	85	
	190	90	
	200	80	6-7
	210	85	
	220	85	8
	230	75	
	240	80	9
	250	75	
	260	80	
	270	80	
	280	75	
stop head motion	290	80	10
	300	70	
	310	75	
	320	70	
	330	65	
	340	70	
	350	70	
	360	70	
	370	65	
	380	60	
	390	65	
	400	60	
	410	65	

Parameter: Surface Skin Temperature
Subject: #4

Date: 5 Aug 86
Time: 1054 - 1059

Event	Time (sec)	Value(F)	Symptom
baseline	-	87.8	
	-	87.8	
	-	87.7	
	-	87.7	
	-	87.7	
start spin	0	88.7	1
	10	88.7	
	20	88.5	
	30	88.5	2
	40	88.4	
	50	88.4	
head motions	60	88.3	
	70	88.3	3
	80	88.3	5
	90	88.2	
	100	88.2	
	110	88.2	
	120	88.2	
	130	88.2	
	140	88.1	
	150	88.1	
	160	88.1	6
	170	88.0	
	180	88.0	
	190	88.0	
	200	88.0	6-7
	210	88.0	
	220	87.9	8
	230	87.9	
	240	87.9	9
	250	87.8	
	260	87.7	
	270	87.6	
	280	87.5	
stop head motion	290	87.4	10
	300	87.4	
	310	87.4	
	320	87.3	
	330	87.3	
	340	87.5	
	350	87.7	
	360	87.9	
	370	88.1	
	380	88.3	
	390	88.6	
	400	88.8	
	410	89.0	

Parameter: Electrocardiogram (EKG) Date: 5 Aug 86
Subject: #4 Time: 1054 - 1059

Event	Time (sec)	Value(Beats/min)	Symptom
baseline	-	108	
	-	102	
	-	102	
	-	102	
	-	114	
start spin	0	123	1
	10	129	
	20	132	
	30	135	2
	40	132	
	50	105	
head motion	60	126	
	70	126	3
	80	132	5
	90	125	
	100	129	
	110	120	
	120	126	
	130	111	
	140	120	
	150	120	
	160	120	6
	170	123	
	180	132	
	190	126	
	200	135	6-7
	210	126	
	220	132	8
	230	114	
	240	126	9
	250	120	
	260	126	
	270	120	
	280	126	
stop head motion	290	120	10
	300	129	
	310	111	
	320	114	
	330	114	
	340	108	
	350	102	
	360	105	
	370	105	
	380	102	
	390	90	
	400	93	
	410	96	

Parameter: Thoracic Respiration | Date: 5 Aug 86
Subject: #4 | Time: 1054 - 1059

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	600/3	
	-	600/4	
	-	600/3	
	-	800/3	
	-	900/2	
start spin	0	1000/2.5	1
	10	1100/3	
	20	700/3.5	
	30	800/3	2
	40	650/3	
	50	500/3.5	
head motions	60	1100/4	
	70	900/5.5	3
	80	1000/3	5
	90	500/1.5	
	100	400/3.5	
	110	300/4.5	
	120	500/4	
	130	700/3.5	
	140	700/3.5	
	150	500/4	
	160	1200/3.5	6
	170	400/4	
	180	700/3.5	
	190	900/4	
	200	1000/2.5	6-7
	210	450/3.5	
	220	1000/3.5	8
	230	900/4.5	
	240	1500/3	9
	250	1100/4	
	260	2100/3	
	270	1600/3.5	
	280	1700/4	
stop head motion	290	1500/4	10
	300	1500/2	
	310	1600/2	
	320	1500/2	
	330	1500/2	
	340	1500/2	
	350	1300/3	
	360	1500/2	
	370	1600/1	
	380	1500/2	
	390	1400/2	
	400	1300/2	
	410	1300/1	

Parameter: Diaphragmatic Respiration — Date: 5 Aug 86
Subject: #4 — Time: 1054 - 1059

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	600/3	
	-	600/4	
	-	600/3	
	-	500/3	
	-	700/2	
start spin	0	800/2.5	1
	10	800/3	
	20	850/3.5	
	30	1200/3	2
	40	900/3	
	50	900/3.5	
head motions	60	1300/4	
	70	1000/5.5	3
	80	1000/3	5
	90	700/1.5	
	100	1000/3.5	
	110	600/4.5	
	120	800/4	
	130	800/3.5	
	140	900/3.5	
	150	500/4	
	160	600/3.5	6
	170	500/4	
	180	500/3.5	
	190	1100/4	
	200	1000/2.5	6-7
	210	700/3.5	
	220	600/3.5	8
	230	700/4.5	
	240	600/3	9
	250	450/4	
	260	500/3	
	270	400/3.5	
	280	600/4	
stop head motion	290	500/4	10
	300	500/2	
	310	400/2	
	320	400/2	
	330	400/2	
	340	400/2	
	350	400/3	
	360	400/2	
	370	500/1	
	380	500/2	
	390	500/2	
	400	500/2	
	410	500/1	

Parameter: Galvanic Skin Reflex (GSR)   Date: 5 Aug 86
Subject: #4   Time: 1054 - 1059

Event	Time (sec)	Value (K)	Symptom
baseline	-	1300	
	-	1300	
	-	1300	
	-	1300	
	-	1300	
start spin	0	1184	1
	10	1104	
	20	1104	
	30	1104	2
	40	1024	
	50	1024	
head motions	60	960	
	70	854	3
	80	854	5
	90	854	
	100	854	
	110	854	
	120	854	
	130	854	
	140	854	
	150	854	
	160	854	6
	170	854	
	180	854	
	190	854	
	200	854	6-7
	210	854	
	220	854	8
	230	854	
	240	854	9
	250	854	
	260	854	
	270	854	
	280	854	
stop head motion	290	854	10
	300	950	
	310	950	
	320	950	
	330	950	
	340	925	
	350	900	
	360	875	
	370	854	
	380	825	
	390	800	
	400	760	
	410	730	

Parameter: Finger Photoplethysmograph
Subject: #5

Date: 12 Aug 86
Time: 1149 - 1152

Event	Time (sec)	Value (%)	Symptom
baseline	-	70	
	-	75	
	-	75	
	-	70	
	-	75	
start spin	0	80	1
	10	85	
	20	80	2
	30	60	
	40	65	
	50	75	
head motions	60	65	
	70	75	
	80	80	6
	90	80	
	100	65	
	110	60	
	120	70	8
	130	60	
	140	65	
	150	65	
stop head motion	160	70	9
	170	65	
	180	60	
	190	60	
	200	60	
	210	60	
	220	60	
	230	55	
	240	60	
	250	60	
	260	60	
	270	65	
	280	70	
	290	60	
	300	60	
	310	60	

Parameter: Surface Skin Temperature
Subject: #5

Date: 12 Aug 86
Time: 1149 - 1152

Event	Time (sec)	Value (F)	Symptom
baseline	-	84.8	
	-	84.8	
	-	84.9	
	-	84.9	
	-	85	
start spin	0	85	1
	10	85	
	20	85.1	2
	30	85.2	
	40	85.2	
	50	85.2	
head motions	60	85.2	
	70	85.2	
	80	85.3	6
	90	85.3	
	100	85.4	
	110	85.5	
	120	85.6	8
	130	85.7	
	140	85.9	
	150	86.1	
stop head motion	160	86.3	9
	170	86.5	
	180	86.7	
	190	86.9	
	200	87.2	
	210	87.5	
	220	87.8	
	230	88.2	
	240	88.5	
	250	88.9	
	260	89.5	
	270	90.0	
	280	90.6	
	290	91.3	
	300	92.0	
	310	92.5	

Parameter: Electrocardiogram (EKG)
Subject: #5

Date: 12 Aug 86
Time: 1149 - 1152

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	54	
	-	60	
	-	54	
	-	54	
	-	60	
start spin	0	78	1
	10	84	
	20	96	2
	30	96	
	40	96	
	50	90	
head motions	60	84	
	70	84	
	80	84	6
	90	78	
	100	72	
	110	66	
	120	48	8
	130	48	
	140	66	
	150	54	
stop head motion	160	60	9
	170	60	
	180	42	
	190	36	
	200	39	
	210	36	
	220	36	
	230	57	
	240	60	
	250	60	
	260	60	
	270	66	
	280	66	
	290	63	
	300	63	
	310	66	

Parameter: Thoracic Respiration
Subject: #5

Date: 12 Aug 86
Time: 1149 - 1152

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	400/4	
	-	400/4	
	-	500/4	
	-	500/4	
	-	600/4	
start spin	0	650/4	1
	10	500/6	
	20	600/6	2
	30	650/5.5	
	40	850/4	
	50	800/4.5	
head motions	60	800/5	
	70	600/4.5	
	80	650/4.5	6
	90	550/4.5	
	100	750/4	
	110	650/5	
	120	850/4.5	8
	130	700/4.5	
	140	900/3.5	
	150	900/3	
stop head motion	160	850/4	9
	170	1000/2	
	180	1100/2	
	190	1100/2	
	200	1100/2	
	210	1000/2	
	220	1200/2	
	230	1100/2	
	240	1100/2	
	250	1100/2	
	260	800/2	
	270	900/2	
	280	900/3	
	290	1000/2	
	300	1000/2	
	310	1000/2	

Parameter: Diaphragmatic Respiration
Subject: #5

Date: 12 Aug 86
Time: 1149 - 1152

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	100/4	
	-	100/4	
	-	100/4	
	-	100/4	
	-	100/4	
start spin	0	450/4	1
	10	500/6	
	20	550/6	2
	30	450/5.5	
	40	450/4	
	50	400/4.5	
head motions	60	350/5	
	70	600/4.5	
	80	650/4.5	6
	90	900/4.5	
	100	1000/4	
	110	850/5	
	120	1200/4.5	8
	130	1200/4.5	
	140	1300/3.5	
	150	1250/3	
stop head motion	160	1400/4	9
	170	1500/2	
	180	1500/2	
	190	1500/2	
	200	1400/2	
	210	1500/2	
	220	1500/2	
	230	1500/2	
	240	1500/2	
	250	1500/2	
	260	1500/2	
	270	1400/2	
	280	1200/2	
	290	1100/2	
	300	1100/3	
	310	1000/2	

Parameter: Galvanic Skin Reflex (GSR)
Subject: #5

Date: 12 Aug 86
Time: 1149 - 1152

Event	Time (sec)	Value (K)	Symptom
baseline	-	46	
	-	46	
	-	46	
	-	46	
	-	46	
start spin	0	46	1
	10	65	
	20	70	2
	30	85	
	40	85	
	50	85	
head motions	60	85	
	70	95	
	80	95	6
	90	135	
	100	140	
	110	120	
	120	175	8
	130	175	
	140	215	
	150	230	
stop head motion	160	240	9
	170	250	
	180	265	
	190	280	
	200	290	
	210	300	
	220	300	
	230	310	
	240	320	
	250	320	
	260	330	
	270	330	
	280	330	
	290	340	
	300	350	
	310	350	

Parameter: Finger Photoplethysmograph
Subject: #6

Date: 13 Aug 86
Time: 1037 - 1045

Event	Time (sec)	Value (%)	Symptom
baseline	-	65	
	-	65	
	-	65	
	-	65	
	-	75	
start spin	0	75	1
	10	80	
	20	75	
	30	75	
	40	75	
	50	80	
head motions	60	85	
	70	90	
	80	80	
	90	95	
	100	85	2
	110	85	
	120	85	
	130	85	
	140	75	
	150	75	
	160	70	
	170	70	
	180	65	
	190	75	
	200	65	
	210	60	
	220	65	
	230	65	3
	240	70	
	250	70	
	260	70	
	270	70	
	280	70	
	290	60	
	300	70	
	310	75	
	320	75	4
	330	75	6-7
	340	75	
	350	65	
	360	70	
	370	75	8
	380	70	
	390	70	9
	400	75	
	410	80	

	420	75
	430	70
stop head motion	440	70
	450	75
	460	70
	470	65
	480	65
	490	65
	500	65
	510	65
	520	60
	530	60
	540	60
	550	65
	560	65
	570	70
	580	70
	590	70
	600	70

Parameter: Surface Skin Temperature　　Date: 13 Aug 86
Subject: #6　　Time: 1037 - 1045

Event	Time (sec)	Value (F)	Symptom
baseline	-	94.8	
	-	94.8	
	-	94.8	
	-	94.8	
	-	94.8	
start spin	0	94.8	1
	10	94.8	
	20	94.8	
	30	94.6	
	40	94.6	
	50	94.6	
head motions	60	94.6	
	70	94.5	
	80	94.5	
	90	94.5	
	100	94.4	2
	110	94.4	
	120	94.4	
	130	94.3	
	140	94.3	
	150	94.2	
	160	94.2	
	170	94.2	
	180	94.1	
	190	94.1	
	200	94.1	
	210	94.1	
	220	94.05	
	230	94.05	3
	240	94.05	
	250	93.9	
	260	93.9	
	270	93.9	
	280	93.9	
	290	93.9	
	300	93.9	
	310	93.8	
	320	93.8	4
	330	93.8	6-7
	340	93.8	
	350	93.8	
	360	93.8	
	370	93.7	8
	380	93.7	
	390	93.7	9
	400	93.7	
	410	93.6	

	420	93.6
	430	93.6
stop head motion	440	93.6
	450	93.6
	460	93.6
	470	93.6
	480	93.6
	490	93.7
	500	93.7
	510	93.7
	520	93.8
	530	93.9
	540	93.9
	550	94.0
	560	94.1
	570	94.2
	580	94.2
	590	94.3
	600	94.3

Parameter: Electrocardiogram (EKG) Date: 13 Aug 86
Subject: #6 Time: 1037 - 1045

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	81	
	-	72	
	-	78	
	-	78	
	-	78	
start spin	0	84	1
	10	90	
	20	90	
	30	78	
	40	78	
	50	72	
head motions	60	72	
	70	78	
	80	84	
	90	78	
	100	78	2
	110	66	
	120	78	
	130	66	
	140	72	
	150	66	
	160	78	
	170	78	
	180	84	
	190	72	
	200	66	
	210	78	
	220	90	
	230	66	3
	240	78	
	250	72	
	260	90	
	270	72	
	280	72	
	290	72	
	300	90	
	310	72	
	320	84	4
	330	78	6-7
	340	78	
	350	78	
	360	102	
	370	72	8
	380	84	
	390	72	9
	400	84	
	410	72	

	420	78
	430	78
stop head motion	440	78
	450	72
	460	63
	470	75
	480	78
	490	78
	500	72
	510	63
	520	63
	530	69
	540	69
	550	72
	560	66
	570	69
	580	69
	590	69
	600	72

Parameter: Thoracic Respiration
Subject: #6

Date: 13 Aug 86
Time: 1037 - 1045

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	300/3	
	-	300/3	
	-	300/3	
	-	300/3	
	-	300/3	
start spin	0	300/4.5	1
	10	350/4.5	
	20	400/3.5	
	30	400/3.5	
	40	400/4	
	50	400/4	
head motions	60	450/4	
	70	300/6	
	80	450/3	
	90	400/4	
	100	500/4	2
	110	300/4	
	120	400/4	
	130	300/3.5	
	140	400/4	
	150	400/4	
	160	350/4	
	170	250/4.5	
	180	450/3	
	190	550/3	
	200	400/4	
	210	250/4	
	220	600/3	
	230	400/2.5	3
	240	500/3	
	250	350/3	
	260	500/2.5	
	270	400/3	
	280	450/3	
	290	450/3	
	300	700/2	
	310	600/1.5	
	320	700/2	4
	330	650/1.5	6-7
	340	550/2	
	350	550/2	
	360	1200/1	
	370	500/2	8
	380	550/2	
	390	600/2.5	9
	400	950/1.5	
	410	800/2	

	420	850/2
	430	600/2
stop head motion	440	1200/1.5
	450	800/1
	460	800/1
	470	900/2
	480	700/2
	490	700/2
	500	600/1
	510	500/2
	520	600/2
	530	600/2
	540	600/2
	550	400/1
	560	500/1
	570	500/2
	580	400/2
	590	400/3
	600	400/3

Parameter: Diaphragmatic Respiration		Date: 13 Aug 86
Subject: #6		Time: 1037 - 1045

Event	Time (sec)	Value(vol/#breath)	Symptom
Baseline	-	250/3	
	-	250/3	
	-	250/3	
	-	250/3	
	-	250/3	
start spin	0	250/4.5	1
	10	250/4.5	
	20	250/3.5	
	30	300/3.5	
	40	300/4	
	50	300/4	
head motions	60	300/4	
	70	450/6	
	80	600/3	
	90	550/4	
	100	400/4	2
	110	300/4	
	120	300/4	
	130	250/3.5	
	140	200/4	
	150	200/4	
	160	200/4	
	170	200/4.5	
	180	250/3	
	190	300/3	
	200	100/4	
	210	300/4	
	220	300/3	
	230	150/2.5	3
	240	250/3	
	250	250/3	
	260	250/2.5	
	270	150/3	
	280	100/3	
	290	100/3	
	300	300/2	
	310	250/1.5	
	320	350/2	4
	330	250/1.5	6-7
	340	350/2	
	350	150/2	
	360	500/1	
	370	450/2	8
	380	400/2	
	390	300/2.5	9
	400	350/1.5	
	410	600/2	

	420	400/2
	430	300/2
stop head motion	440	500/1.5
	450	500/1
	460	600/1
	470	600/2
	480	600/2
	490	600/2
	500	500/1
	510	500/2
	520	500/2
	530	500/2
	540	500/2
	550	500/1
	560	400/1
	570	300/2
	580	300/2
	590	300/3
	600	300/3

Parameter: Galvanic Skin Reflex (GSR)
Subject: #6

Date: 13 Aug 84
Time: 1037 -- 1045

Event	Time (sec)	Value (K)	Symptom
baseline	-	845	
	-	845	
	-	845	
	-	845	
	-	845	
start spin	0	845	1
	10	850	
	20	850	
	30	860	
	40	875	
	50	885	
head motions	60	890	
	70	890	
	80	880	
	90	880	
	100	880	2
	110	880	
	120	900	
	130	880	
	140	900	
	150	880	
	160	900	
	170	890	
	180	870	
	190	880	
	200	880	
	210	880	
	220	880	
	230	845	3
	240	840	
	250	820	
	260	810	
	270	810	
	280	810	
	290	730	
	300	730	
	310	770	
	320	830	4
	330	810	6-7
	340	870	
	350	850	
	360	770	
	370	770	8
	380	770	
	390	840	9
	400	790	
	410	750	

	420	790
	430	810
stop head motion	440	810
	450	820
	460	825
	470	830
	480	830
	490	835
	500	840
	510	845
	520	850
	530	854
	540	854
	550	854
	560	854
	570	854
	580	860
	590	865
	600	870

Parameter: Finger Photoplethysmograph
Subject: #7

Date: 14 Aug 86
Time: 1013 - 1017

Event	Time (sec)	Value (%)	Symptom
baseline	-	70	
	-	70	
	-	70	
	-	60	
	-	60	
start spin	0	70	1
	10	85	
	20	70	
	30	65	
	40	70	
	50	75	
head motions	60	70	
	70	70	
	80	65	2
	90	60	
	100	60	3
	110	60	
	120	60	
	130	55	4-5
	140	55	
	150	55	6-7
	160	60	
	170	60	8
	180	50	
	190	50	
	200	45	
	210	35	
	220	30	
	230	25	9
	240	30	
stop head motion	250	30	10
	260	25	
	270	25	
	280	25	
	290	30	
	300	35	
	310	35	
	320	35	
	330	30	
	340	35	
	350	30	
	360	30	
	370	35	
	380	35	
	390	40	
	400	40	
	410	40	

Parameter: Surface Skin Temperature | Date: 14 Aug 86
Subject: #7 | Time: 1013 - 1017

Event	Time (sec)	Value (F)	Symptom
baseline	-	93.3	
	-	93.3	
	-	93.3	
	-	93.3	
	-	93.3	
start spin	0	93.3	1
	10	93.3	
	20	93.2	
	30	93.2	
	40	93.2	
	50	93.1	
head motions	60	93.1	
	70	93.1	
	80	93.1	2
	90	93.1	
	100	93	3
	110	93	
	120	93	
	130	93	4-5
	140	93	
	150	93	6-7
	160	93	
	170	93	8
	180	92.9	
	190	92.9	
	200	92.8	
	210	92.8	
	220	92.8	
	230	92.7	9
	240	92.7	
stop head motion	250	92.6	10
	260	92.6	
	270	92.5	
	280	92.5	
	290	92.6	
	300	92.6	
	310	92.6	
	320	92.7	
	330	92.7	
	340	92.7	
	350	92.8	
	360	92.9	
	370	93.0	
	380	93.1	
	390	93.5	
	400	93.8	
	410	94.1	

Parameter: Electrocardiogram (EKG) Date: 14 Aug 86
Subject: #7 Time; 1013 - 1017

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	69	
	-	78	
	-	69	
	-	60	
	-	60	
start spin	0	63	1
	10	66	
	20	63	
	30	69	
	40	66	
	50	81	
head motions	60	81	
	70	96	
	80	78	2
	90	90	
	100	78	3
	110	72	
	120	90	
	130	72	4-5
	140	87	
	150	75	6-7
	160	72	
	170	84	8
	180	72	
	190	78	
	200	78	
	210	69	
	220	72	
	230	66	9
	240	72	
stop head motion	250	69	10
	260	66	
	270	63	
	280	63	
	290	66	
	300	60	
	310	66	
	320	60	
	330	63	
	340	60	
	350	60	
	360	66	
	370	66	
	380	69	
	390	69	
	400	66	
	410	66	

Parameter: Thoracic Respiration
Subject: #7

Date: 14 Aug 86
Time: 1013 - 1017

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	500/3	
	-	500/2	
	-	500/3	
	-	450/3	
	-	500/3	
start spin	0	550/3.5	1
	10	550/3.5	
	20	450/3.5	
	30	400/3.5	
	40	550/3.5	
	50	500/4	
head motions	60	600/4	
	70	500/3.5	
	80	650/2.5	2
	90	700/3	
	100	700/3	3
	110	750/2.5	
	120	750/2.5	
	130	800/2	4-5
	140	800/2	
	150	750/2	6-7
	160	800/2	
	170	850/2	8
	180	700/3	
	190	850/1.5	
	200	700/2.5	
	210	700/2.5	
	220	700/2	
	230	750/2	9
	240	800/2	
stop head motion	250	900/2	10
	260	700/3	
	270	600/3	
	280	800/2	
	290	800/3	
	300	900/1	
	310	900/1	
	320	900/1	
	330	800/2	
	340	800/1	
	350	700/2	
	360	700/2	
	370	800/1	
	380	700/2	
	390	700/2	
	400	700/2	
	410	800/2	

Parameter: Diaphragmatic Respiration   Date: 14 Aug 86
Subject: #7   Time: 1013 - 1017

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	500/3	
	-	550/2	
	-	550/3	
	-	600/3	
	-	600/3	
start spin	0	600/3.5	1
	10	500/3.5	
	20	400/3.5	
	30	400/3.5	
	40	650/3.5	
	50	500/4	
head motions	60	350/4	
	70	150/3.5	
	80	450/2.5	2
	90	500/3	
	100	300/3	3
	110	350/2.5	
	120	400/2.5	
	130	400/2	4-5
	140	350/2	
	150	300/2	6-7
	160	300/2	
	170	300/2	8
	180	150/3	
	190	200/1.5	
	200	150/2.5	
	210	250/2.5	
	220	200/2	
	230	150/2	9
	240	200/2	
stop head motion	250	150/2	10
	260	200/3	
	270	250/3	
	280	300/2	
	290	300/3	
	300	350/1	
	310	300/1	
	320	300/1	
	330	350/2	
	340	350/1	
	350	350/2	
	360	350/2	
	370	400/1	
	380	400/2	
	390	400/2	
	400	400/2	
	410	400/2	

Parameter: Galvanic Skin Reflex (GSR)
Subject: #7

Date: 14 Aug 86
Time: 1013 - 1017

Event	Time (sec)	Value (K)	Symptom
baseline	-	854	
	-	854	
	-	854	
	-	854	
	-	854	
start spin	0	840	1
	10	820	
	20	840	
	30	840	
	40	840	
	50	760	
head motions	60	800	
	70	800	
	80	800	2
	90	830	
	100	840	3
	110	840	
	120	830	
	130	860	4-5
	140	850	
	150	840	6-7
	160	800	
	170	800	8
	180	800	
	190	810	
	200	860	
	210	880	
	220	880	
	230	890	9
	240	920	
stop head motion	250	880	10
	260	870	
	270	870	
	280	870	
	290	854	
	300	870	
	310	854	
	320	854	
	330	870	
	340	880	
	350	854	
	360	870	
	370	870	
	380	880	
	390	870	
	400	870	
	410	563	

Parameter: Finger Photoplethysmograph
Subject: #8

Date: 14 Aug 86
Time: 1203 - 1207

Event	Time (sec)	Value (%)	Symptom
baseline	-	45	
	-	45	
	-	50	
	-	55	
	-	70	
start spin	0	75	1
	10	75	
	20	75	
	30	75	
	40	70	
	50	70	
head motions	60	70	
	70	80	
	80	80	
	90	75	
	100	75	
	110	75	
	120	75	2
	130	70	3
	140	75	
	150	75	
	160	75	
	170	75	4
	180	80	6
	190	70	
	200	75	
stop head motion	210	70	9
	220	65	
	230	60	
	240	50	
	250	50	
	260	50	
	270	50	
	280	45	
	290	50	
	300	55	
	310	45	
	320	50	

Parameter: Electrocardiogram (EKG) Date: 14 Aug 86
Subject: #8 Time: 1203 - 1207

Event	Time (sec)	Value(beat/min)	Symptom
baseline	-	72	
	-	72	
	-	66	
	-	66	
	-	69	
start spin	0	72	1
	10	96	
	20	108	
	30	116	
	40	90	
	50	87	
head motions	60	90	
	70	81	
	80	93	
	90	87	
	100	96	
	110	90	
	120	108	2
	130	99	3
	140	117	
	150	108	
	160	96	
	170	102	4
	180	90	6
	190	84	
	200	78	
stop head motion	210	78	9
	220	78	
	230	93	
	240	87	
	250	90	
	260	96	
	270	87	
	280	75	
	290	78	
	300	84	
	310	78	
	320	78	

Parameter: Thoracic Respiration
Subject: #8

Date: 14 Aug 86
Time: 1203 - 1207

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	600/2	
	-	700/1.5	
	-	700/1.5	
	-	700/2	
	-	750/2	
start spin	0	750/1.5	1
	10	900/2	
	20	1000/2	
	30	1000/2	
	40	800/2	
	50	750/2.5	
head motions	60	800/3	
	70	700/3	
	80	750/3	
	90	600/4	
	100	700/2.5	
	110	850/3	
	120	650/3.5	2
	130	800/3	3
	140	750/3.5	
	150	700/3.5	
	160	800/4	
	170	700/3.5	4
	180	650/4	6
	190	450/4	
	200	400/4	
stop head motion	210	450/4.5	9
	220	550/3	
	230	550/3	
	240	600/2	
	250	650/2	
	260	650/2	
	270	650/2	
	280	650/2	
	290	600/2	
	300	650/2	
	310	600/2	
	320	650/2	

Parameter: Diaphragmatic Respiration | Date: 14 Aug 86
Subject: #8 | Time: 1203 - 1207

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	650/2	
	-	650/1.5	
	-	650/1.5	
	-	600/2	
	-	550/2	
start spin	0	500/1.5	1
	10	600/2	
	20	750/2	
	30	1000/2	
	40	1100/2	
	50	1100/2.5	
head motions	60	850/3	
	70	750/3	
	80	800/3	
	90	900/4	
	100	850/2.5	
	110	900/3	
	120	900/3.5	2
	130	950/3	3
	140	850/3.5	
	150	800/3.5	
	160	950/4	
	170	925/3.5	4
	180	850/4	6
	190	800/4	
	200	800/4	
stop head motion	210	800/4.5	9
	220	750/3	
	230	750/3	
	240	750/2	
	250	700/2	
	260	700/2	
	270	700/2	
	280	650/2	
	290	650/2	
	300	600/2	
	310	600/2	
	320	600/2	

Parameter: Galvanic Skin Reflex (GSR) Date: 14 Aug 86
Subject: #8 Time: 1203 - 1207

Event	Time (sec)	Value (K)	Symptom
baseline	-	1100	
	-	1100	
	-	1100	
	-	1100	
	-	1000	
start spin	0	1100	1
	10	950	
	20	900	
	30	900	
	40	950	
	50	975	
head motions	60	975	
	70	854	
	80	854	
	90	854	
	100	854	
	110	760	
	120	854	2
	130	900	3
	140	900	
	150	925	
	160	854	
	170	760	4
	180	800	6
	190	760	
	200	854	
stop head motion	210	854	9
	220	854	
	230	800	
	240	750	
	250	800	
	260	800	
	270	800	
	280	750	
	290	750	
	300	750	
	310	800	
	320	800	

Parameter: Finger Photoplethysmograph | Date: 18 Aug 86
Subject: #9 | Time: 1036 - 1041

Event	Time (sec)	Value (%)	Symptom
baseline	-	75	
	-	75	
	-	70	
	-	75	
	-	75	
start spin	0	80	1
	10	85	
	20	85	
	30	75	
	40	80	
	50	80	
head motions	60	80	
	70	75	
	80	80	
	90	75	
	100	75	
	110	70	
	120	70	
	130	65	3
	140	65	
	150	50	5
	160	55	
	170	60	
	180	55	
	190	50	7
	200	60	
	210	55	9
	220	55	
	230	60	
	240	50	
	250	45	
	260	45	
stop head motion	270	40	10
	280	40	
	290	45	
	300	50	
	310	35	
	320	40	
	330	40	
	340	40	
	350	40	
	360	45	
	370	50	
	380	50	
	390	50	
	400	60	
	410	50	

Parameter: Surface Skin Temperature
Subject: #9

Date: 18 Aug 86
Time: 1036 - 1041

Event	Time (sec)	Value (F)	Symptom
baseline	-	93.4	
	-	93.4	
	-	93.4	
	-	93.4	
	-	93.4	
start spin	0	93.4	1
	10	93.4	
	20	93.4	
	30	93.4	
	40	93.4	
	50	93.4	
head motions	60	93.4	
	70	93.4	
	80	93.4	
	90	93.4	
	100	93.4	
	110	93.4	
	120	93.4	
	130	93.4	3
	140	93.4	
	150	93.3	5
	160	93.2	
	170	93.2	
	180	93.2	
	190	93.2	7
	200	93.1	
	210	93.1	9
	220	93.1	
	230	93	
	240	93	
	250	92.9	
	260	92.9	
stop head motion	270	92.9	10
	280	93	
	290	93.1	
	300	93.3	
	310	93.5	
	320	93.7	
	330	93.8	
	340	94	
	350	94.2	
	360	94.4	
	370	94.5	
	380	94.6	
	390	94.8	
	400	95	
	410	95.1	

Parameter: Electrocardiogram (EKG) Date: 18 Aug 86
Subject: #9 Time: 1036 - 1041

Event	Time (sec)	Value(Beats/min)	Symptom
baseline	-	87	
	-	90	
	-	87	
	-	93	
	-	102	
start spin	0	120	1
	10	120	
	20	126	
	30	126	
	40	123	
	50	123	
head motions	60	126	
	70	123	
	80	120	
	90	114	
	100	123	
	110	117	
	120	114	
	130	114	3
	140	114	
	150	117	5
	160	117	
	170	120	
	180	114	
	190	102	7
	200	120	
	210	120	9
	220	111	
	230	117	
	240	108	
	250	99	
	260	99	
stop head motion	270	108	
	280	84	
	290	96	
	300	90	
	310	96	
	320	84	
	330	90	
	340	84	
	350	90	
	360	90	
	370	84	
	380	84	
	390	84	
	400	84	
	410	90	

Parameter: Thoracic Respiration
Subject: #9

Date: 18 Aug 86
Time: 1036 - 1041

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	700/3	
	-	700/3	
	-	750/4	
	-	800/4	
	-	900/4	
start spin	0	800/4	1
	10	800/5	
	20	800/4	
	30	800/4.5	
	40	800/5	
	50	700/4.5	
head motions	60	650/5	
	70	650/5	
	80	600/4	
	90	650/5	
	100	650/4.5	
	110	650/4	
	120	750/4	
	130	750/3.5	3
	140	750/3.5	
	150	700/4	5
	160	800/2.5	
	170	850/3	
	180	850/2.5	
	190	750/3	7
	200	850/2.5	
	210	950/2.5	9
	220	900/3	
	230	900/2.5	
	240	900/3	
	250	850/3.5	
	260	900/2.5	
stop head motion	270	900/2	10
	280	800/3	
	290	900/2	
	300	900/2	
	310	900/2	
	320	900/2	
	330	750/1.5	
	340	700/2	
	350	600/1.5	
	360	600/2	
	370	600/1.5	
	380	600/2	
	390	650/2	
	400	600/2	
	410	650/2	

Parameter: Diaphragmatic Respiration
Subject: #9

Date: 18 Aug 86
Time: 1036 - 1041

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	1600/3	
	-	1600/3	
	-	1600/4	
	-	1600/4	
	-	1600/4	
start spin	0	1500/4	1 .
	10	1500/5	
	20	1500/4	
	30	1600/4.5	
	40	1500/5	
	50	1500/4.5	
head motions	60	1400/5	
	70	1100/5	
	80	1250/4	
	90	1500/5	
	100	1200/4.5	
	110	1300/4	
	120	1100/4	
	130	1000/3.5	3
	140	1000/3.5	
	150	1300/4	5
	160	1300/2.5	
	170	1700/3	
	180	1800/2.5	
	190	1500/3	7
	200	1800/2.5	
	210	1850/2.5	9
	220	1750/3	
	230	1600/2.5	
	240	1800/3	
	250	1750/3.5	
	260	1850/2.5	
stop head motion	270	1900/2	10
	280	1800/3	
	290	1800/2	
	300	1700/7	
	310	1600/2	
	320	1600/2	
	330	1600/1.5	
	340	1600/2	
	350	1600/1.5	
	360	1500/2	
	370	1500/2	
	380	1500/2	
	390	1500/2	
	400	1500/2	
	410	1500/2	

Parameter: Galvanic Skin Reflex (GSR)
Subject: #9

Date: 18 Aug 86
Time: 1036 - 1041

Event	Time (sec)	Value (K)	Symptom
baseline	-	563	
	-	563	
	-	563	
	-	563	
	-	563	
start spin	0	563	1
	10	563	
	20	420	
	30	420	
	40	480	
	50	480	
head motions	60	480	
	70	500	
	80	510	
	90	470	
	100	450	
	110	480	
	120	520	
	130	563	3
	140	580	
	150	600	5
	160	600	
	170	610	
	180	620	
	190	600	7
	200	580	
	210	563	9
	220	563	
	230	600	
	240	640	
	250	680	
	260	700	
stop head motion	270	700	10
	280	750	
	290	760	
	300	760	
	310	780	
	320	760	
	330	760	
	340	760	
	350	740	
	360	760	
	370	760	
	380	770	
	390	800	
	400	800	
	410	800	

Parameter: Finger Photoplethysmograph   Date: 19 Aug 86
Subject: #10   Time: 1033 - 1038

Event	Time (sec)	Value (%)	Symptom
baseline	-	80	
	-	75	
	-	70	
	-	70	
	-	75	
start spin	0	80	1
	10	95	
	20	90	
	30	90	
	40	85	
	50	80	
head motions	60	75	
	70	75	
	80	75	
	90	70	
	100	70	
	110	70	2-3
	120	70	
	130	75	
	140	75	
	150	60	
	160	70	
	170	60	
	180	55	4
	190	60	
	200	70	
	210	70	
	220	55	6
	230	55	7-8
	240	60	
	250	60	
	260	70	9
	270	70	
stop head motion	280	70	10
	290	75	
	300	70	
	310	60	
	320	60	
	330	65	
	340	60	
	350	60	
	360	60	
	370	60	
	380	55	
	390	55	
	400	55	
	410	55	

Parameter: Surface Skin Temperature   Date: 19 Aug 86
Subject: #10   Time: 1033 - 1038

Event	Time (sec)	Value (F)	Symptom
baseline	-	94.8	
	-	94.8	
	-	95.1	
	-	95.1	
	-	95.1	
start spin	0	95.1	
	10	95.1	
	20	95	
	30	95	
	40	94.9	
	50	94.9	
head motions	60	94.9	
	70	94.8	
	80	94.8	
	90	94.8	
	100	94.8	
	110	94.7	2-3
	120	94.7	
	130	94.7	
	140	94.6	
	150	94.6	
	160	94.5	
	170	94.5	
	180	94.4	4
	190	94.4	
	200	94.3	
	210	94.3	
	220	94.3	6
	230	94.2	7-8
	240	94.2	
	250	94.2	
	260	94.1	9
	270	94.1	
stop head motion	280	94	10
	290	95.5	
	300	95.3	
	310	95.3	
	320	95.2	
	330	95.2	
	340	95.4	
	350	95.5	
	360	95.6	
	370	95.6	
	380	95.6	
	390	95.8	
	400	95.9	
	410	95.9	

Parameter: Electrocardiogram (EKG)
Subject: #10

Date: 19 Aug 86
Time: 1033 - 1038

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	81	
	-	87	
	-	96	
	-	78	
	-	87	
start spin	0	96	1
	10	96	
	20	102	
	30	96	
	40	93	
	50	93	
head motions	60	90	
	70	90	
	80	78	
	90	84	
	100	87	
	110	93	2-3
	120	84	
	130	90	
	140	96	
	150	102	
	160	72	
	170	84	
	180	84	4
	190	90	
	200	102	
	210	90	
	220	90	6
	230	96	7-8
	240	84	
	250	90	
	260	84	9
	270	90	
stop head motion	280	90	10
	290	84	
	300	96	
	310	78	
	320	96	
	330	84	
	340	87	
	350	87	
	360	96	
	370	90	
	380	84	
	390	78	
	400	84	
	410	75	

Parameter: Thoracic Respiration | Date: 19 Aug 86
Subject: #10 | Time: 1033 - 1038

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	350/2	
	-	350/2	
	-	350/2.5	
	-	400/3	
	-	300/3	
start spin	0	400/3	1
	10	500/3	
	20	500/3	
	30	600/3	
	40	600/2.5	
	50	550/3	
head motions	60	500/3	
	70	300/3.5	
	80	400/4	
	90	300/3	
	100	450/3	
	110	500/2.5	2-3
	120	550/3	
	130	550/2.5	
	140	550/3	
	150	600/3	
	160	700/2.5	
	170	600/3	
	180	600/3	4
	190	500/2.5	
	200	750/2	
	210	800/2	
	220	900/1.5	6
	230	700/2	7-8
	240	750/2	
	250	750/2	
	260	800/1.5	9
	270	650/2	
stop head motion	280	750/2	10
	290	700/2	
	300	800/2	
	310	1200/2	
	320	1200/1.5	
	330	1300/1	
	340	1300/1.5	
	350	1300/1.5	
	360	1200/2	
	370	1000/1.5	
	380	600/2	
	390	750/2	
	400	750/2	
	410	750/2	

Parameter: Diaphragmatic Respiration   Date: 19 Aug 86
Subject: #10   Time: 1033 - 1038

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	200/2	
	-	200/2	
	-	200/2.5	
	-	250/3	
	-	200/3	
start spin	0	150/3	1
	10	200/3	
	20	200/3	
	30	200/3	
	40	250/2.5	
	50	200/3	
head motions	60	200/3	
	70	150/3.5	
	80	250/4	
	90	150/3	
	100	200/3	
	110	250/2.5	2-3
	120	400/3	
	130	400/2.5	
	140	250/3	
	150	250/3	
	160	350/2.5	
	170	350/3	
	180	400/3	4
	190	350/2.5	
	200	500/2	
	210	650/2	
	220	700/1.5	6
	230	600/2	7-8
	240	600/2	
	250	800/2	
	260	1200/1.5	9
	270	300/2	
stop head motion	280	300/2	10
	290	300/2	
	300	350/2	
	310	400/2	
	320	500/1.5	
	330	500/1	
	340	600/1.5	
	350	400/1	
	360	400/1.5	
	370	350/1.5	
	380	300/2	
	390	300/1.5	
	400	300/2	
	410	250/2	

Parameter: Galvanic Skin Reflex (GSR) Date: 19 Aug 86
Subject: #10 Time: 1033 -1038

Event	Time (sec)	Value (K)	Symptom
baseline	-	1200	
	-	1400	
	-	1200	
	-	1100	
	-	850	
start spin	0	750	1
	10	700	
	20	700	
	30	700	
	40	750	
	50	750	
head motions	60	800	
	70	825	
	80	854	
	90	854	
	100	900	
	110	900	2-3
	120	854	
	130	950	
	140	950	
	150	950	
	160	854	
	170	870	
	180	900	4
	190	900	
	200	900	
	210	900	
	220	854	6
	230	854	7-8
	240	854	
	250	854	
	260	854	9
	270	854	
stop head motion	280	854	10
	290	800	
	300	800	
	310	800	
	320	825	
	330	825	
	340	825	
	350	800	
	360	800	
	370	854	
	380	854	
	390	750	
	400	750	
	410	750	

Parameter: Finger Photoplethysmograph | Date: 22 Aug 86
Subject: #11 | Time: 1512 - 1516

Event	Time (sec)	Value (%)	Symptom
baseline	-	65	
	-	55	
	-	75	
start spin	0	75	1
	10	85	
	20	85	
	30	75	
	40	70	
	50	65	
head motions	60	75	
	70	75	
	80	70	
	90	65	
	100	65	2
	110	65	
	120	65	
	130	50	
	140	50	5-6
	150	50	8
	160	45	
	170	45	9
	180	45	
	190	45	10
stop head motion	200	40	
	210	40	
	220	25	
	230	30	
	240	25	
	250	25	
	260	35	
	270	25	
	280	25	
	290	35	
	300	30	
	310	35	
	320	20	
	330	20	
	340	20	
	350	25	
	360	25	
	370	25	
	380	20	

Parameter: Facial Photoplethysmograph
Subject: #11

Date: 22 Aug 86
Time: 1512 - 1516

Event	Time (sec)	Value (%)	Symptom
baseline	-	30	
	-	30	
	-	30	
start spin	0	30	1
	10	40	
	20	40	
	30	45	
	40	30	
	50	30	
head motions	60	25	
	70	25	
	80	30	
	90	30	
	100	30	2
	110	40	
	120	40	
	130	60	
	140	40	5-6
	150	40	8
	160	30	
	170	30	9
	180	25	
	190	30	10
stop head motion	200	20	
	210	30	
	220	50	
	230	45	
	240	50	
	250	30	
	260	30	
	270	35	
	280	20	
	290	40	
	300	40	
	310	50	
	320	25	
	330	30	
	340	25	
	350	30	
	360	30	
	370	25	
	380	20	

Parameter: Surface Skin Temperature
Subject: #11

Date: 22 Aug 86
Time: 1512 - 1516

Event	Time (sec)	Value (F)	Symptom
baseline	-	88.9	
	-	88.9	
	-	88.9	
start spin	0	88.9	1
	10	88.9	
	20	88.8	
	30	88.8	
	40	88.7	
	50	88.7	
head motions	60	88.6	
	70	88.6	
	80	88.6	
	90	88.5	
	100	88.5	2
	110	88.4	
	120	88.4	
	130	88.3	
	140	88.3	5-6
	150	88.2	8
	160	88.2	
	170	88.2	9
	180	88.2	
	190	88.2	10
stop head motion	200	88.2	
	210	88.2	
	220	88.2	
	230	88.2	
	240	88.7	
	250	89	
	260	89.5	
	270	90	
	280	90.3	
	290	90.7	
	300	91	
	310	91.2	
	320	91.4	
	330	91.5	

Parameter: Electrocardiogram (EKG) Date: 22 Aug 86
Subject: #11 Time: 1512 -1516

Event	Time (sec)	Value(beats/min)	Symptom
baseline	-	90	
	-	90	
	-	105	
start spin	0	132	1
	10	138	
	20	129	
	30	129	
	40	120	
	50	123	
head motions	60	126	
	70	126	
	80	126	
	90	114	
	100	114	2
	110	108	
	120	111	
	130	99	
	140	108	5-6
	150	108	8
	160	108	
	170	84	9
	180	108	
	190	96	10
stop head motion	200	108	
	210	96	
	220	102	
	230	108	
	240	105	
	250	99	
	260	102	
	270	102	
	280	96	
	290	102	
	300	90	
	310	102	
	320	96	
	330	96	
	340	96	
	350	96	
	360	96	
	370	96	
	380	90	

Parameter: Thoracic Respiration | Date: 22 Aug 86
Subject: #11 | Time: 1512 - 1516

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	500/3	
	-	500/3	
	-	550/4	
start spin	0	600/4	1
	10	600/4	
	20	600/4.5	
	30	700/4	
	40	700/4.5	
	50	600/4.5	
head motions	60	600/4.5	
	70	550/4	
	80	500/5.5	
	90	500/4.5	
	100	500/4.5	2
	110	350/4	
	120	300/5	
	130	350/3.5	
	140	350/4	5-6
	150	450/3	8
	160	500/3	
	170	350/3	9
	180	700/3	
	190	150/2	10
stop head motion	200	600/3	
	210	800/2.5	
	220	1100/3	
	230	1200/3	
	240	1200/3	
	250	1200/3	
	260	1200/3	
	270	1100/3	
	280	1200/3	
	290	1000/3	
	300	1000/3	
	310	1100/3	
	320	1000/3	
	330	750/3	
	340	700/3	
	350	700/3	
	360	1000/3	
	370	850/3	
	380	800/3	

Parameter: Diaphragmatic Respiration
Subject: #11

Date: 22 Aug 86
Time: 1512 - 1516

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	250/3	
	-	300/3	
	-	300/4	
start spin	0	300/4	1
	10	400/4	
	20	350/4.5	
	30	350/4	
	40	400/4.5	
	50	350/4.5	
head motions	60	400/4.5	
	70	600/4	
	80	400/5.5	
	90	350/4.5	
	100	400/4.5	2
	110	400/4	
	120	400/5	
	130	350/3.5	
	140	450/4	5-6
	150	450/3	8
	160	600/3	
	170	550/3	9
	180	900/3	
	190	550/2	10
stop head motion	200	800/3	
	210	800/2.5	
	220	1000/3	
	230	1100/3	
	240	1100/3	
	250	1200/3	
	260	1200/3	
	270	1200/3	
	280	1200/3	
	290	1200/3	
	300	1100/3	
	310	1000/3	
	320	1000/3	
	330	900/3	
	340	800/2.5	
	350	800/3	
	360	800/3	
	370	750/3	
	380	750/3	

Parameter: Galvanic Skin Reflex (GSR)
Subject: #11

Date: 22 Aug 86
Time: 1512 - 1516

Event	Time (sec)	Value (K)	Symptom
baseline	-	30	
	-	30	
	-	30	
start spin	0	15	1
	10	15	
	20	15	
	30	15	
	40	15	
	50	15	
head motions	60	15	
	70	15	
	80	15	
	90	15	
	100	15	2
	110	15	
	120	15	
	130	15	
	140	15	5-6
	150	15	8
	160	15	
	170	15	9
	180	15	
	190	15	10
stop head motion	200	15	
	210	100	
	220	200	
	230	300	
	240	400	
	250	500	
	260	550	
	270	600	
	280	640	
	290	680	
	300	700	
	310	740	
	320	800	
	330	820	
	340	840	
	350	854	

Parameter: Finger Photoplethysmograph | Date: 26 Aug 86
Subject: #12 | Time: 1033 - 1040

Event	Time (sec)	Value (%)	Symptom
baseline	-	70	
	-	75	
	-	80	
	-	80	
	-	80	
start spin	0	80	1
	10	80	
	20	85	
	30	80	
	40	80	
	50	75	
head motions	60	75	
	70	80	
	80	75	
	90	75	
	100	60	
	110	70	
	120	80	2
	130	75	
	140	75	
	150	80	
	160	70	
	170	75	
	180	80	
	190	85	
	200	75	
	210	80	
	220	75	
	230	80	
	240	80	
	250	75	4
	260	80	
	270	80	
	280	85	6
	290	85	8
	300	75	
	310	75	
	320	65	
	330	65	9
	340	65	
	350	65	
	360	70	
	370	70	
stop head motion	380	70	
	390	75	
	400	70	
	410	75	

420	75
430	75
440	65
450	75
460	65
470	60
480	65
490	65
500	65
510	65
520	65
530	65
540	60
550	60
560	70
570	65

Parameter: Facial Photoplethysmograph
Subject: #12

Date: 26 Aug 86
Time: 1033 - 1040

Event	Time (sec)	Value (%)	Symptom
baseline	-	50	
	-	42	
	-	50	
	-	50	
	-	50	
start spin	0	50	1
	10	50	
	20	50	
	30	50	
	40	50	
	50	50	
head motions	60	50	
	70	60	
	80	65	
	90	65	
	100	60	
	110	60	
	120	60	2
	130	65	
	140	65	
	150	65	
	160	60	
	170	65	
	180	60	
	190	60	
	200	60	
	210	60	
	220	60	
	230	60	
	250	70	4
	260	70	
	270	70	
	280	70	6
	290	75	8
	300	75	
	310	75	
	320	75	
	330	80	9
	340	80	
	350	80	
	360	80	
	370	80	
stop head motion	380	80	
	390	70	
	400	70	
	410	64	

420	56
430	80
440	75
450	70
460	56
470	49
480	56
490	50
500	50
510	50
520	56
530	56
540	42
550	60
560	64
570	50

Parameter: Surface Skin Temperature | Date: 26 Aug 86
Subject: #12 | Time: 1033 - 1040

Event	Time (sec)	Value (F)	Symptom
baseline	-	83.2	
	-	83.2	
	-	83.2	
	-	83.1	
	-	83.1	
start spin	0	83.1	1
	10	83.1	
	20	83.1	
	30	83.1	
	40	83.1	
	50	83.1	
head motions	60	83.1	
	70	83.1	
	80	83.1	
	90	83.1	
	100	83.1	
	110	83	
	120	83	2
	130	83	
	140	83	
	150	83	
	160	83	
	170	83	
	180	82.9	
	190	82.9	
	200	82.9	
	210	82.9	
	220	82.9	
	230	82.9	
	240	82.9	
	250	82.9	4
	260	82.8	
	270	82.8	
	280	82.8	6
	290	82.8	8
	300	82.8	
	310	82.8	
	320	82.8	
	330	82.7	7
	340	82.7	
	350	82.7	
	360	82.7	
	370	82.7	
stop head motion	380	82.7	
	390	82.7	
	400	82.7	
	410	82.7	

420	82.7
430	82.7
440	82.8
450	82.8
460	82.8
470	82.8
480	82.8
490	82.8
500	82.8
510	82.8
520	82.9
530	82.9
540	82.9
550	82.9
560	82.9
570	82.9

Parameter: Electrocardiogram (EKG)   Date: 26 Aug 86
Subject: #12   Time: 1033 - 1040

Event	Time (sec)	Value(Beats/min)	Symptom
baseline	-	72	
	-	78	
	-	72	
	-	72	
	-	78	
start spin	0	84	1
	10	78	
	20	84	
	30	84	
	40	84	
	50	84	
head motions	60	84	
	70	84	
	80	90	
	90	96	
	100	90	
	110	84	
	120	84	2
	130	90	
	140	90	
	150	84	
	160	84	
	170	84	
	180	84	
	190	90	
	200	90	
	210	90	
	230	96	
	240	102	
	250	102	4
	260	108	
	270	108	
	280	108	6
	290	102	8
	300	108	
	310	108	
	320	102	
	330	102	9
	340	102	
	350	108	
	360	108	
	370	114	
stop head motion	380	108	
	390	93	
	400	93	
	410	84	

420	84
430	78
440	84
450	90
460	78
470	78
480	84
490	78
500	75
510	93
520	78
530	72
540	75
550	78
560	81
570	78

Parameter: Thoracic Respiration
Subject: #12

Date: 26 Aug 86
Time: 1033 - 1040

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	650/1.5	
	-	650/2	
	-	600/2.5	
	-	600/2	
	-	550/2.5	
start spin	0	500/4	1
	10	350/5	
	20	450/4	
	30	500/4	
	40	600/2.5	
	50	650/2	
head motions	60	300/4	
	70	250/4.5	
	80	200/5	
	90	300/4	
	100	450/3	
	110	500/3	
	120	500/3	2
	130	500/2.5	
	140	500/3	
	150	450/3	
	160	500/4	
	170	400/3	
	180	500/2.5	
	190	600/1.5	
	200	500/3	
	210	500/2.5	
	220	500/3	
	230	400/3	
	240	400/2	
	250	400/3	4
	260	400/3	
	270	450/2.5	
	280	500/2.5	6
	290	450/2.5	8
	300	450/2.5	
	310	400/2.5	
	320	300/3	
	330	400/3	9
	340	500/3	
	350	400/3	
	360	400/2.5	
	370	500/4	
stop head motion	380	350/3	
	390	300/3	
	400	500/2	
	410	500/1.5	

420	750/2
430	500/2
440	500/2
450	550/1
460	600/1.5
470	450/2.5
480	450/1.5
490	400/2
500	400/2
510	450/1.5
520	500/2
530	500/2
540	500/2
550	400/2
560	550/2
570	700/1.5

Parameter: Diaphragmatic Respiration
Subject: #12

Date: 26 Aug 86
Time: 1033 - 1040

Event	Time (sec)	Value(vol/#breath)	Symptom
baseline	-	650/1.5	
	-	700/2	
	-	650/2.5	
	-	500/2	
	-	500/2.5	
start spin	0	500/4	1
	10	500/5	
	20	600/4	
	30	700/4	
	40	850/2.5	
	50	900/2	
head motions	60	600/4	
	70	700/4.5	
	80	600/5	
	90	800/4	
	100	700/3	
	110	700/3	
	120	700/3	2
	130	600/2.5	
	140	600/3	
	150	700/3	
	160	700/4	
	170	600/3	
	180	750/2.5	
	190	750/1.5	
	200	750/3	
	210	700/2.5	
	220	700/3	
	230	750/3	
	240	750/2	
	250	700/3	4
	260	700/3	
	270	750/2.5	
	280	650/2.5	6
	290	750/2.5	8
	300	750/2.5	
	310	800/2.5	
	320	650/3	
	330	650/3	9
	340	700/3	
	350	650/3	
	360	700/2.5	
	370	650/4	
stop head motion	380	500/3	
	390	500/3	
	400	500/2	
	410	550/1.5	

420	500/2
430	500/2
440	550/2
450	500/1
460	450/1.5
470	500/2.5
480	500/1.5
490	450/2
500	450/2
510	400/1.5
520	400/2
530	400/2
540	500/2
550	400/2
560	500/2
570	500/1.5

Parameter: Galvanic Skin Reflex (GSR)
Subject: #12

Date: 26 Aug 86
Time: 1033 - 1040

Event	Time (sec)	Value (K)	Symptom
baseline	-	54	
	-	70	
	-	90	
	-	90	
	-	110	
start spin	0	150	1
	10	150	
	20	150	
	30	150	
	40	150	
	50	150	
head motions	60	150	
	70	150	
	80	150	
	90	150	
	100	160	
	110	160	
	120	160	2
	130	160	
	140	170	
	150	180	
	160	190	
	170	200	
	180	215	
	190	238	
	200	235	
	210	235	
	220	250	
	230	260	
	240	260	
	250	260	4
	260	260	
	270	238	
	280	238	6
	290	238	8
	300	238	
	310	260	
	320	290	
	330	320	9
	340	350	
	350	370	
	360	420	
	370	420	
stop head motion	380	420	
	390	420	
	400	460	
	410	460	

420	460
430	490
440	490
450	490
460	490
470	490
480	490
490	520
500	510
510	520
520	520
530	520
540	520
550	520
560	320
570	563

Appendix C MOTION SICKNESS (TAPE EDIT)

	Baseline Pre-Spin	0-3 Spin	4-7 Pre-Nausea	8-10 Nausea	10+ Post
1	15- 30	30-120	120-140	140-175	175-265
	a= 1000-1010	a= 1000-1065	a= 1000-1014	a= 1000-1023	a=1000-1066
2	385-415	415-485	485-510	510-550	550-615
	a= 1010-1031	a= 1065-1114	a= 1014-1031	a= 1023-1050	a=1066-1114
3	730-760	760-825	825-870	870-895	895-955
	a= 0-32	a= 0-70	a= 0-48	a= 0-28	a= 0-65
4	245-275	275-310	310-380	380-420	420-540
	a= 1031-1051	a= 1114-1138	a= 1031-1080	a= 1050-1076	a=1114-1199
5	635-665	665-685	685-720	720-745	745-820
	a= 1051-1072	a= 1138-1152	a= 1080-1104	a= 1076-1093	a=1199-1251
6	970-1000	1000-1140	1140-1170	1170-1220	1220-1310
	a= 1072-1092	a= 1152-1248	a= 1104-1124	a= 1093-1126	a=1251-1313
7	1430-1460	1460-1520	1520-1545	1545-1585	1585-1670
	a= 1092-1112	a= 1248-1288	a= 1124-1140	a= 1126-1151	a=1313-1370
8	0- 25	25- 95	95-110	110-125	125-275
	a= 32-58	a= 70-144	a= 48-64	a= 28-44	a= 65-221
9	430-460	460-530	530-560	560-600	600-690
	a= 1112-1132	a= 1288-1334	a= 1140-1161	a= 1151-1177	a=1370-1429
10	790-880	880-950	950-990	990-1018	1018-1103
	a= 58-150	a= 144-214	a= 64-106	a= 44-74	a= 221-305
11	0- 20	20- 80	80- 95	95-125	125-210
	a= 1132-1145	a= 1334-1374	a= 1161-1171	a= 1177-1196	a=1429-1485
12	570-600	600-715	715-745	745-790	790-885
	a= 150-180	a= 214-326	a= 106-137	a= 74-123	a=305-395
13	975-1005	1005-1110	1110-1123	1123-1140	1140-1180
	a= 1145-1165	a= 1374-1442	a= 1171-1181	a= 1196-1207	a=1485-1510

RESPIRATION

Baseline normal <= 15 bpm)	Baseline tachypneic (> 15 bpm)
3, 8, 10, 12	1, 2, 4, 5, 6, 7, 9, 11, 13

MOTION SICKNESS (TAPE EDIT)

#1 Add 180 sec after stop head motion
GSR - not valid
2 EEG (A) - good
3 EEG (B) - use only after symptoms 10+
4 EEG (C) - not valid
5 ENG (H) - good
7 ENG (V) - good (positive slow EEG)

#2 Add 130 sec after stop head motion
GSR - decreased
2 EEG (A) - use only after symptoms 10+
3 EEG (B) - not valid
4 EEG (C) - not valid
5 ENG (H) - not valid
7 ENG (V) - good (+ slow EEG)

#3 Add 120 sec after stop head motion
GSR - increased
2 EEG (A) - good
3 EEG (B) - not valid
4 EEG (C) - not valid
5 ENG (H) - good (+ slow EEG)
7 ENG (V) - good (+ slow EEG)
12,13 Switch EIG and EGG

#4 Add 240 sec after stop head motion
GSR - decreased
2 EEG (A) - good
3 EEG (B) - not valid
4 EEG (C) - not valid
5 ENG (H) - not valid
7 ENG (V) - good (no slow EEG)
12,13 Switch EIG and EGG

#5 Add 150 sec after stop head motion
GSR - increased
2 EEG (A) - not valid
3 EEG (B) - not valid
4 EEG (C) - not valid
5 ENG (H) - good (+ slow EEG)
7 ENG (V) - good (+ slow EEG)
12,13 Switch EIG and EGG
EKG - arrhythmia: ++

#6		Add 180 sec after stop head motion
		GSR - minimal decrease
	2	EEG (A) - not valid
	3	EEG (B) - not valid
	4	EEG (C) - not valid
	5	ENG (H) - good
	7	ENG (V) - good (+ slow EEG)
	12,13	Switch EIG and EGG
#7		Add 170 sec after stop head motion
		GSR - minimal increase
	2	EEG (A) - good after B = 1497
	3	EEG (B) - good after B = 1497
	4	EEG (C) - not valid
	5	ENG (H) - good (+ slow EEG)
	7	ENG (V) - not valid
#8		Add 300 sec after stop head motion
		GSR - decreased
	2	EEG (A) - not valid
	3	EEG (B) - good
	4	EEG (C) - not valid
	5	ENG (H) - overloaded but (+ slow EEG) not val
	7	ENG (V) - overloaded but (+ slow EEG) not val
#9		Add 180 sec after stop head motion
		GSR - increased
	2	EEG (A) - not valid
	3	EEG (B) - not valid
	4	EEG (C) - not valid
	5	ENG (H) - good (+ slow EEG)
	7	ENG (V) - good (+ slow EEG)
		Resp(D) - greater amplitude than Thoracic
#10		Add 170 sec after stop head motion
		GSR - minimal increase
	2	EEG (A) - use only baseline and 10+
	3	EEG (B) - not valid
	4	EEG (C) - not valid
	5	ENG (H) - not valid
	7	ENG (V) - good (+ slow EEG)
#11		Add 170 sec after stop head motion
		GSR - increased
	2	EEG (A) - good
	3	EEG (B) - good
	4	EEG (C) - not connected (not valid)
	5	ENG (H) - good (+ slow EEC)
	7	ENG (V) - good (+ slow EEG)

#12 Add 190 sec after stop head motion

GSR - increased
2 EEG (A) - good (+ slow EEG)
3 EEG (B) - good
7 EEG (C) - good (+ slow EEG)
5 ENG (H) - not valid
4 ENG (V) - not valid

#13 Add 80 sec after stop head motion

GSR - slight decrease
2 EEG (A) - not valid
3 EEG (B) - not valid
4 EEG (C) - not valid
5 ENG (H) - good (+ slow EEG slightly)
7 ENG (V) - good (+ slow EEG slightly)

VITA

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Biophysical data were collected on human volunteers to study the effects of the motion sickness syndrome. Physiological parameters were analyzed by descriptive statistical methods and by means of a spectrum analyzer. Descriptive statistical analysis showed at least five separate physiological parameters were linearly correlated to a motion sickness symptom index. Spectral analysis showed definite frequency and amplitude shifts during the onset of motion sickness for various parameters. Low frequency brain wave activity on the order of 0.1 Hz was discovered as the subject approached nausea.

A multiple linear regression model was constructed from the correlated data obtained by descriptive statistics. Six separate physiological parameters were useful in describing a predictive motion sickness model that can be used as a major element in developing a complete biofeedback system for countering the effects of motion sickness.